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Comparative Evaluation Of Effectiveness Of Articulating Paper And T-Scan In The Assessment Of Occlusion In Removable Prostheses – A Systematic Review

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Abstract

Statement Of Problem:
Correct occlusion is one of the most integral parts of any prosthetic rehabilitation. It is important to assess the occlusal contacts which are required in order to maintain the static and dynamic relation of the teeth and to understand the occlusal contacts which may act as interference leading to detrimental effects. Hence, assessing occlusion using the methods available helps prevents complications, minimizes patient discomfort and maximizes the esthetic and functional outcomes of prosthodontic treatments. However, literature regarding the use of different methods in assessing occlusion and their effectiveness in removable prosthesis is very limited.

Purpose:
The purpose of this study is to address the following review question: "Is there a difference in the effectiveness of articulating paper and T-Scan in the assessment of occlusion in removable prostheses?"

Material And Methods:
Comprehensive literature searches were accomplished in different electronic databases including Medline/PubMed, Scopus and DOAJ. Only articles published in English language evaluating occlusion using articulating paper and T-scan were included. The last search was accomplished on February 29, 2024. The primary outcome assessed was the occlusion. Additional outcomes including patient satisfaction and masticatory efficiency in terms of assessing occlusion were evaluated. Cochrane RoB-2 tool was used for risk of bias assessment of RCT study and ROBINS-I tool for the non-RCT studies.

Results:
Four studies were included in the statistical analysis performed in which the removable prosthesis was used by 42 patients. The results of the systematic review for assessment of occlusion presented significant difference in the effectiveness of the occlusal adjustments made using T-Scan and that with the articulating paper where, T-Scan was proven to be a better method of occlusal assessment. The secondary outcomes of this study concluded T-Scan has shown a better masticatory efficiency and patient satisfaction. Also, T-Scan is more consistent and reliable method than articulating paper.

Conclusion:
A thorough understanding of occlusion and discrepancies related to occlusion can be obtained by properly using T-Scan analyzing method. Also, patient satisfaction and masticatory efficiency were better for T-Scan than articulating paper. Nevertheless, to offer more precise evidence-based recommendations, it is worthwhile to perform additional well designed and well-implemented clinical trials with a long-term follow-up period.

Clinical Significance:
As the population ages, there arises the need for effective prosthetic rehabilitation, necessitating accurate assessment methods for occlusion in removable prosthesis. Understanding the strength and weakness of

articulating paper and T-Scan can guide the clinicians in selecting the most appropriate tool for assessment of the occlusion which in turn will improve the effectiveness of the removable prosthesis and enhancing patient satisfaction.

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I. Introduction

Complete or partial edentulism refers to the condition in which there is absence of all or few of the natural teeth.[1] According to the World Health Organization criteria, patients with complete or partial edentulism fall under the category of physically impaired, disabled and handicap because of their inability to properly masticate and speak. Along with this it also affects one's esthetics.[2] For patients with edentulism, complete rehabilitation is required which is achieved by fixed or removable prosthesis. Removable prosthesis includes complete or partial dentures, tooth or implant supported overdentures.[3]

Achieving proper occlusion is of utmost importance for successful prosthetic treatment and more care needs to be taken it patients with complete edentulism as any occlusal disharmony may lead to unfavorable displacing forces leading to discomfort to the patient, mucosal trauma or emotional disturbances.[4] Stability which is one of the basic requirements of removable dentures can also be attained by occlusal harmony.[5] Occlusion also plays an important role in temporomandibular disorders where, it underscores the intricate interplay between the TMJ, masticatory muscles and dental occlusion.[6] As a result, assessing occlusion becomes crucial since patients with complete edentulism lack periodontal support, making it difficult for them to sense the premature contacts present in the prosthesis.[7]

The most commonly available methods for evaluating occlusion includes qualitative methods like wax, elastomeric impressions, articulating papers and quantitative methods like T-Scan and photo-occlusion.[8] Articulating paper has been a staple in dental practice providing a visual representation of occlusal contacts based on the size and intensity of the markings.[9] However its limitations include subjective interpretation of these markings, easy removal of the markings by saliva and potential inaccuracies due to varying thickness such as pseudo contacts.[7]

In contrast, T-Scan technology offers more sophisticated approach, allowing for dynamic and quantitative analysis of the occlusal forces starting from first point of contact to maximum intercuspation. It also offers information regarding occlusion-disocclusion timing which helps in fine tune adjustment of the occlusion, ensures even force distribution and ensures proper movements of the jaw during excursive movements.[10] T-scan thus provides a more objective assessment of occlusion and enhances the precision of occlusal adjustment.[11] In a study conducted by Kelvin I A and Sarah Qadeer, they concluded that the computerized occlusal analyzing system is a better occlusal indicator when compared with other conventional indicators.[12]

Hence the comparative effectiveness of these two methods in assessing occlusion in removable prosthesis is a critical area of research, particularly given the increasing prevalence of edentulism and the need for effective prosthetic solutions. This systematic review aims to explore these comparative aspects, focusing on their implications for the management of occlusion in patients with complete or partial edentulism requiring removable prosthesis.

II. Materials And Methods:

The study was registered in the PROSPERO platform (CRD42024516303). This systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines and the Population (P), Intervention (I), Comparison (C), Outcome (O), Study design (S) approach.

The PICOS question was defined as follows: the population comprised of patients with complete or partial edentulous arches which are treated with conventional or implant supported removable prosthesis; the intervention included the assessment of occlusal contacts made using T-Scan system; the control included the assessment of occlusal contacts made using articulating paper of any thickness; the outcome was effectiveness of the occlusal indicator compared in assessing the occlusal contacts and the study design randomized controlled trials or experimental studies, non-randomized trials and prospective studies.

The electronic data resources consulted for elaborated search were PubMed, DOAJ and Google Scholar with controlled vocabulary and free text terms. The search methodology combined the use of key words and Medical Subject Headings (MeSH) terms using the databases as listed in Table 1.

All the titles and abstracts were initially assessed based on their inclusion and exclusion criteria. Inclusion criteria are as follows: Studies including participants with complete edentulism and treated with conventional or implant-supported complete denture prosthesis irrespective of age, gender, studies including assessment of occlusal forces/contacts made using T-Scan system and articulating papers, studies providing information about occlusal contacts, occlusal forces, masticatory efficiency in both groups, studies published in English language only, studies published until February 2024, RCTs or quasi experimental studies, non-

randomized trials, prospective studies only, studies with full-text articles only. Exclusion criteria are as follows: Studies involving patients not providing informed consent, studies without a valid comparison group, studies providing only abstract and not full text. Observational studies, Review reports, case series, in-vitro and animal studies were excluded. (Table 2).

Two reviewers assessed the titles and abstracts to identify potentially eligible studies. Any queries were discussed with a third reviewer. Then the full text of the articles selected based on the title and abstract were critically assessed by the same reviewers. The recorded data items like the participants, settings, the interventions, the comparators, the outcome measures, study design, statistical analysis and results and all other relevant data (funding, conflict of interest etc.) were carefully and accurately extracted from all included studies (Table 3 and 4). Because of the high degree of heterogenicity in terms of different studies and methodologies, a meta-analysis was not possible.

For randomized controlled trials, Cochrane RoB-2 tool[13] was used for quality assessment. According to this tool, risk of bias is assessed at study level under following domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and other bias. Quality assessment of the selected non-RCT studies was performed using Risk of Bias for Non-Randomized studies (ROBINS-I) tool.[14] The ROBINS-I tool covers 7 domains through which bias might be introduced into a non-RCT: bias due to confounding, selection bias, miss-classification bias, bias due to deviation from intended interventions, bias due to missing data, bias in management of outcomes, reporting bias. Each study will be categorized as having a low, high, or unclear risk of bias based on these criteria.

III. Results:

The initial electronic database search on PubMed/MEDLINE and DOAJ resulted in 1765 titles. 749 were cited as duplicates. After screening the abstracts, 91 relevant titles were selected by two independent reviewers. Following examination and discussion by the reviewers, 91 articles were selected for full-text evaluation. Hand searching of the reference lists of the selected studies did not deliver additional papers. Of the 91 articles that were evaluated only 25 met the eligibility criteria. After application of the inclusion and exclusion criteria and handling of the PICOS question, 4 studies were included in the qualitative synthesis (Figure1). The selected studies were then subjected to data extraction, risk of bias assessment and quantitative synthesis. The summary of the studies selected are listed in Table 4. Among the included studies, one study[16] was randomized controlled crossover trial and three studies[15, 17, 18] were non-randomized prospective clinical studies.

Total of 42 participants have participated in the selected studies, irrespective of the gender as mentioned in the inclusion criteria, with the mean age ranging from 40-75 years. Out of the 4 selected studies 2 studies[15, 18] included participants with completely edentulous mandibular arch with dentate maxillary arch while other 2 articles[16, 17] included participants with completely edentulous maxillary and mandibular arches. All the articles compared the digital method of analyzing occlusion- T-Scan with articulating papers of varying thickness which is 50 microns[16], 100 microns[18]. Follow-up period ranged from 3 months to 18 months.

One of the 4 included studies, Alagwany et al[16] is a crossover RCT which showed moderate risk of bias (Figure 2). Other 3 included studies are non-RCT of which one study[17] showed moderate risk of bias and two studies[15, 18] showed low risk of bias. The effectiveness of T-Scan and articulating paper was assessed for following parameters: patient satisfaction, masticatory efficiency and classification of occlusion. The results of the study revealed that the complete dentures assessed using T-Scan showed greater patient satisfaction as compared to articulating paper. In terms of masticatory efficiency, it was found that the occlusal records assessed using T-Scan increased the masticatory efficiency of the dentures as compared to articulating paper. In terms of occlusion, authors concluded significant agreement and moderate correlation between T-Scan and articulating paper but T-Scan system has been more consistent and reproducible method to analyze occlusion

IV. Discussion:

From the available evidence in this review, the answer to the research question was determined: T-Scan has been proven to be more effective in assessment of occlusion as compared to articulating paper. Of the 4 studies included in this systematic review, study by Shawky A. et al was found to be low risk of bias.[15] This study concluded that the use of T-Scan device allowed better occlusal adjustment in case of implant supported overdenture and resulting in lower crestal bone loss in group I which assessed occlusion using T-Scan rather than group II which assessed occlusion using articulating papers.

In a study by Alagwany et al,[16] which is a crossover randomized controlled trial, this study assessed patients' satisfaction and masticatory efficiency as the parameters to understand the effectiveness of the T-Scan vs articulating paper. This study showed moderate risk of bias as the information related to randomization and allocation concealment was inadequate and it also showed reporting bias. The results of which were that the group with articulating paper recorded significant increase in the masticatory efficiency and patient satisfaction for 1 week as compared to the group with T-Scan, while there was no significant difference between both the groups

when followed for 3 and 6 months and hence it concluded that complete dentures assessed using T-Scan showed greater patient satisfaction and masticatory efficiency as compared to complete dentures assessed using articulating paper.

In a study by Floriani et al,[17] the author assessed the efficiency of digital and analogue method of occlusal indicator in terms of static and dynamic occlusion. This study showed moderate risk of bias. The results of this study showed that there was significant agreement and moderate correlation of the digital and analogue methods during the centric and eccentric movements irrespective of the type of complete denture which is conventional or implant supported. They also concluded that even though there was moderate amount of correlation, the digital system has been more consistent and reproducible method to assess the occlusion.

In a study by Saud et al,[18] the aim of the study was to compare the use of T-Scan and articulating paper for occlusal analysis of the implant supported prosthesis as any premature occlusal contact would result in unwanted stresses to be transmitted to the implants. As a result, here the efficiency of T-Scan and articulating paper was assessed on the basis of stress distribution after making occlusal corrections. This study showed a low risk of bias. The results of this study found higher micro strain values around implants among articulating paper group than T-Scan group and the difference in the mean was statistically not significant under bilateral loading and statistically significant under unilateral loading. This study concluded that articulating papers can still be a reliable method for occlusal analysis and adjustments if they are used correctly but only during centric movements. During the eccentric movements of mandible, T-Scan is more accurate and allows better occlusal stress distribution. Also, T-Scan provides us with the valuable information regarding force intensity and occlusal timings.

The bias assessment for the three studies reveals varying levels of risk of bias. Shawky[15] and Saud[18] both exhibit low risk of bias across all categories, suggesting that these studies are well-conducted with minimal biases, making their findings reliable. In contrast, Alagwany[16] and Floriana[17] has a moderate risk of bias due to unclear risks in confounding bias and bias related to deviations from intended interventions. Although most other biases are assessed as low risk, these uncertainties warrant some caution when interpreting the study's results. Overall, the findings from Shawky[15] and Saud[18] can be considered more dependable than those from Alagwany[16] and Floriana[17].

Limitations of this systematic review includes that only articles published in English language were included. Also, only 2 out of the 4 selected studies actually assessed the occlusion as the factor of comparing the effectiveness of the articulating paper and T-Scan. Further exploration is needed to understand occlusion specifically in removable prosthesis. Lastly, the data obtained is not adequately robust and due to the heterogeneity in studies and limited number of trials meta-analysis was not possible. Hence, in order to offer more specific evidence-based guidance regarding the effectiveness of the articulating paper and T-Scan in assessing occlusion for removable prosthesis, additional well designed and well conducted clinical trials are further recommended.

V. Conclusion:

1. According to the evidences available, T-Scan system has been proven to be a consistent and reproducible method to analyze occlusion in removable prosthesis as well.
2. A thorough understanding of occlusion and the discrepancies related to it can be obtained from properly performed T-Scan occlusal analysis recordings.
3. The study also concluded patient satisfaction and masticatory efficiency was better for occlusion assessed using T-Scan than the articulating paper. This comprehension lessens the follow-up visit complications, and provides a more consistent course of treatment.

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Search	Actions	Details	Query	Results	Time
#5	•••	›	Search: **(((#1) AND (#2)) AND (#3)) AND (#4)**	10	13:58:54
#4	•••	›	Search: **((((occlusal contacts) OR (occlusal forces)) OR (bite)) OR (occlusion)) OR (masticatory efficiency)**	316,962	13:58:22
#3	•••	›	Search: **(articulating paper) OR (occlusal analyser)**	15,297	13:57:22
#2	•••	›	Search: **((T-Scan) OR (quantitative method)) OR (radionuclide imaging)**	2,299,319	13:56:49
#1	•••	›	Search: **((((((edentulous mouth) OR (edentulism)) OR (patients)) OR (completely edentulous)) AND (complete dentures)) OR (dentures)) OR (implant supported overdentures)**	55,535	13:55:35

Table 1 Search strategy using key words

Eligibility Criteria	
Inclusion criteria	**Exclusion criteria**
Articles following the PICO format	Studies involving patients not providing informed consent
Articles published in English language only	Studies without a valid comparison group
Studies published till February 2024	Observational studies, review reports, case series, in-vitro and animal studies
RCTs or experimental studies, Non RCTs prospective, clinical studies only	Studies providing only abstract
Studies with full text articles	

Table 2 Inclusion and Exclusion criteria

Study ID	Place of study	Study design	Sample size	Age	Gender	Type of denture	Intervention	Comparison	Outcomes assessed	Follow-up	Conclusion	crestal bone height T scan	crestal bone height A paper	micro strains bilateral loading	
Shawky 2021	Egypt	clinical study	14	50-65	14/0	mandibular implant supported complete denture	T-Scan III Sensor support and proper size of pressure sensors were chosen and guided by the T-Scan support into the hand piece	straight articulating paper was used of thickness 50 µ and width 20 mm	crestal bone height change	6,12,18 months	It could be concluded that the use of t scan III device allow for better occlussal adjustment in case of implant supported lower single denture than articulating paper and resulting in less vertical bone loss around the supporting dental implants	6m: 0.232+-0.024 12m:0.212+-0.04 18m: 1+-0.07	0.247+-0.04 0.278+-0.1 1.12+-0.51		
Alagwany 2022	Egypt	crossover RCT	10	55-65	not mentioned	complete dentures retained by two implants	occlusal adjustment was done by T-scan system	occlusal adjustment done by articulating paper	patient satisfaction, masticatory efficiency	3,6 months	It was found that T scan recorded a significant increase in masticatory efficiency and patient satisfaction for 1 week after insertion and there was no significant difference between the two groups for 3& 6 months after insertion				
Floriana 2022	Brazil	clinical study	11	40-75	2/9	implant supported conventional complete denture	T-Scan Novus digital occlusal analysis system	articulating paper (Contacto). Thickness - 100um	classification of occlusion	NA	The digital and analog methods showed a significant agreement and moderate correlation, irrespective of the type of complete denture. The T-Scan III digital system seems to be a consistent and reproducible method to analyze occlusion				
Saud 2023	Egypt	clinical study	7	not mentioned	7/0	mandibular implant supported complete denture	prosthesis occlusally adjusted according to T-scan occlusal analysis.	prosthesis occlusally adjusted according to articulating paper occlusal analysis	micro strains induced during unilateral and bilateral loading	NA	T-scan allows better occlusal stresses distribution as it brings additional information regarding force intensity and occlusal timing resulting in less stresses transmitted around implants.	-	-	mesial:51.79+-19.15 distal: 24.46+-9.36	mesial:48.04+-4.15 distal: 33.39+-29.37

Table 3 Study characteristics

Study ID	Place of study	Study design	Sample size	Age	Gender	Type of denture	Intervention	Comparison	Outcomes assessed	Follow-up	Conclusion
Shawky 2021	Egypt	clinical study	14	50-65	14/0	mandibular implant supported complete denture	T-Scan III Sensor support and proper size of pressure sensors were chosen and guided by the T-Scan support into the hand piece	straight articulating paper was used of thickness 50 µ and width 20 mm	crestal bone height change	6,12,18 months	It could be concluded that the use of t scan III device allows for better occlusal adjustment in case of implant supported lower single denture than articulating paper and resulting in less vertical bone loss around the supporting dental implants
Alagwany 2022	Egypt	crossover RCT	10	55-65	not mentioned	complete dentures retained by two implants	occlusal adjustment was done by T-scan system	occlusal adjustment done by articulating paper	patient satisfaction, masticatory efficiency	3,6 months	It was found that T scan recorded a significant increase in masticatory efficiency and patient satisfaction for 1 week after insertion and there was no significant difference between the two groups for 3& 6 months after insertion
Floriana 2022	Brazil	clinical study	11 11/11	40-75	2/9	implant supported conventional complete denture	T-Scan Novus digital occlusal analysis system	articulating paper (Contacto). Thickness - 100um	classification of occlusion	NA	The digital and analog methods showed a significant agreement and moderate correlation, irrespective of the type of complete denture. The T-Scan III digital system seems to be a consistent and reproducible method to analyze occlusion

Saud 2023	Egypt	clinical study	7	not mentioned	7/0	mandibular implant supported complete denture	prosthesis occlusally adjusted according to T-scan occlusal analysis.	prosthesis occlusally adjusted according to articulating paper occlusal analysis	micro strains induced during unilateral and bilateral loading	NA	T-scan allows better occlusal stresses distribution as it brings additional information regarding force intensity and occlusal timing resulting in less stresses transmitted around implants.

Table 4 Data extraction

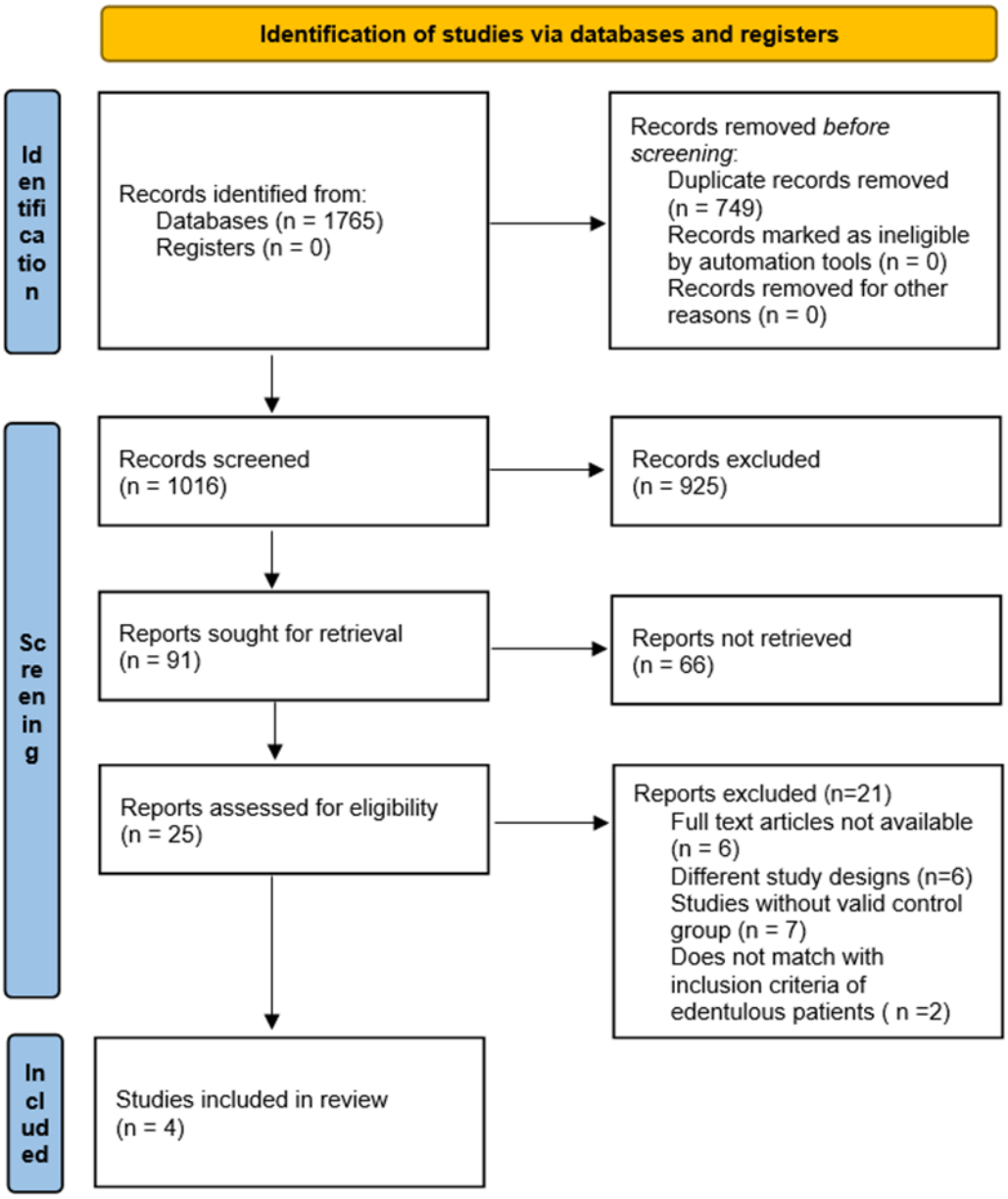

Figure 1 Prisma flowchart

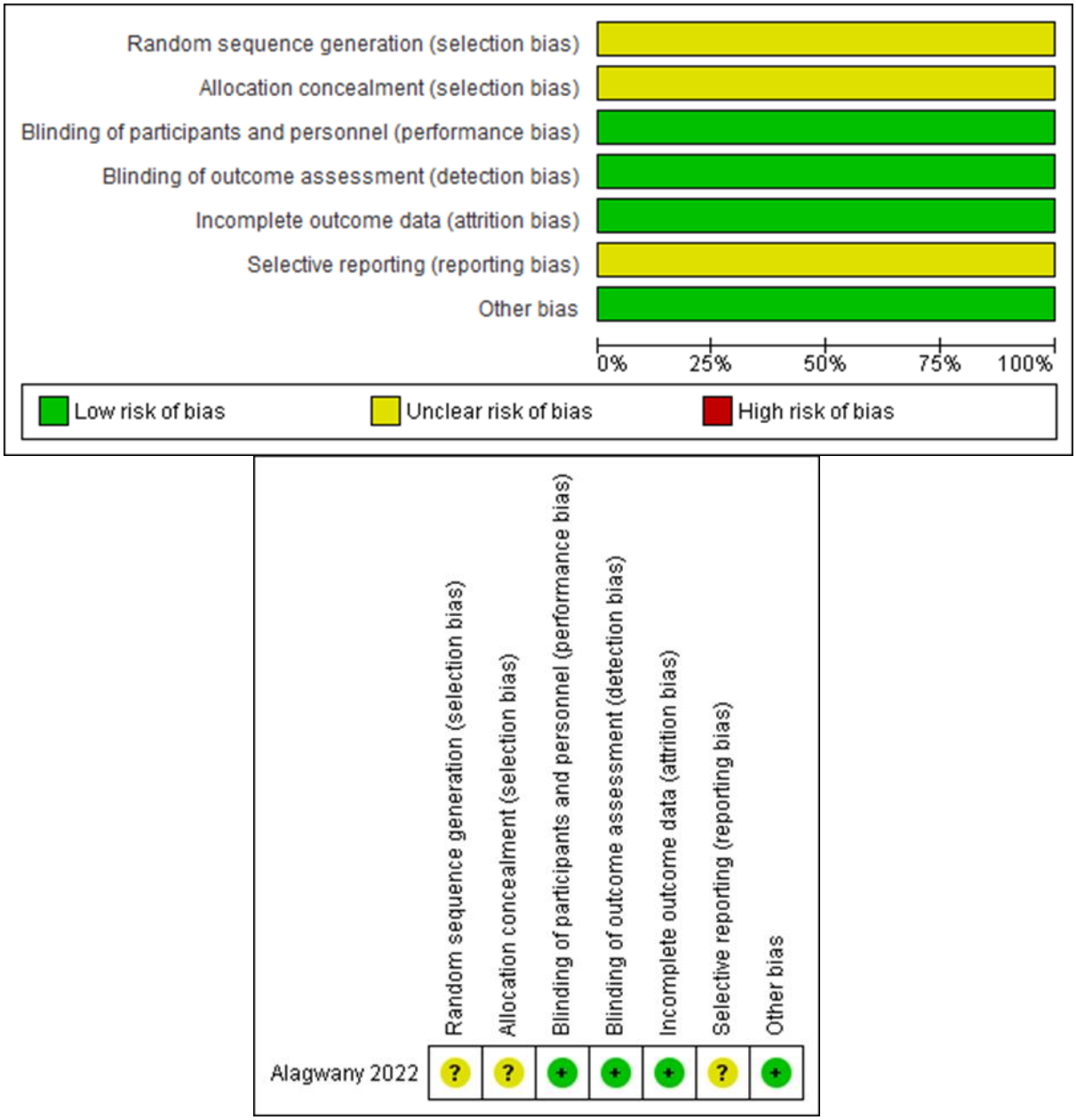

Figure 2. Risk of bias assessment