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REVIEW PAPER

Vertical Ridge Augmentation Using Distraction Osteogenesis Versus Autogenous Bone Grafting: A Systematic Review and Meta-Analysis

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Abstract

Aim The aim of this systematic review was to systematically assess the papers comparing the surgical techniques of Alveolar Distraction Osteogenesis(ADO) and Autogenous Bone grafting (ABG) for Vertical Ridge Augmentation in terms of bone gain, bone resorption and incidences of complications.

Metholodology The review was registered on PROSPERO with the ID : CRD42021237671. A broad electronic survey was conducted in the PubMed, Scopus, Web of Science, Cochrane Library, and Virtual Health Library databases of all studies published till 08/03/2022. Four studies fulfilled the criteria to carry out a meta-analysis a in which a total of 58 patients underwent ADO and 43 patients for ABG. A total of 133 implants were placed in the ABG group and 124 in the ADO group.

Statistical Analysis DerSimonian–Laird estimator of variance was used for Random effect meta-analysis. The estimates of an intervention were expressed as the odds ratio (OR) and standard mean difference (SMD) in millimeters.

Results There was statistically significant difference in terms of bone height gain with SMD of − 0.78 (95% 0.04–1.55) in ABG. Bone resorption and complications were statistically insignificant with SMD of 0.52 (95% − 1.59 to 0.56) and OR 0.55 (95% 0.18–1.70), respectively.

PROSPERO Registration ID: CRD42021237671.

Keywords Vertical ridge augmentation · Alveolar distraction osteogenesis · Autogenous bone grafting

Introduction

Dental rehabilitation using implants is a widely accepted treatment option for completely or partially edentulous patients. Adequate bone volume is a prerequisite for successful implant treatment and a pleasing aesthetic result. Reduced bone volume can be due to trauma, dental extraction, pathological conditions etc. The rate of bone resorption following loss of teeth can be as high as 25–40% in the first two years [1]. An edentulous ridge, with vertically deficient alveolar ridge does not allow use of implants of adequate dimensions due to anatomical limitations such as presence of the nasal cavity, the proximity of maxillary sinus, inferior alveolar nerve etc. [2]. This renders use of various bone augmentation techniques, such as Bone grafting (autograft, allograft or xenograft), Guided Bone Regeneration (GBR) & Alveolar Distraction Osteogenesis (ADO) necessary [3].

Autogenous bone grafting (ABG) is the conventional method for alveolar reconstruction with acceptable success and survival rates of dental implants. It has excellent osteoconductive, osteoinductive, and osteogenic properties. Its use was first described by Brånemark et al. in 1970s for dental implants, and is now a well-accepted treatment [4].

ADO, was introduced as an alternative to ABG in 1996 by Chin and Toth and has become popular over the last two

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decades [5]. ADO is a technique of gradual bone lengthening using the body's natural ability to regenerate bone. Soft tissue is also simultaneously formed in this technique unlike other techniques [6].

Systematic reviews (SR) in literature have previously compared ADO with other bone regenerations techniques of GBR, inlay and onlay bone grafting [7–9]. Our SR is unique as it aimed to include only comparative clinical trials and retrospective study comparing surgical techniques of ADO and ABG for vertical ridge augmentation in terms of vertical bone height gain, bone resorption, complications, implant survival and success rate.

Materials and Methods

Protocol Registration

This SRMA was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines 2020. The review was registered on PROSPERO on 29/03/2021, in database registry (CRD-rigister@york.ac.uk/www.york.ac.uk/inst/crd) with Registration ID CRD42021237671 to avoid duplication of systematic review.

Search Strategy

The electronic survey was conducted in the PubMed, Scopus, Web of Science, Cochrane Library, and Virtual Health Library databases. All the relevant studies available in the literature till 08/03/2022 were included. The key words used were a combination of medical subject heading (MeSH) descriptors: "Vertically deficient ridge" AND "Distraction osteogenesis" "Vertical augmentation" AND "Distraction osteogenesis" AND "Bone graft" "Bone grafting" AND "Distraction osteogenesis" "Vertical augmentation" AND "Autogenous bone graft" "Alveolar distraction" AND "Bone grafting" AND "Implant". The grey literature (Google Scholar) and the Clinical Trials Registry (clinicaltrials.gov) were also searched. The search protocol

Table 1 Participants, intervention, comparator, outcome criteria

PICO question	
Participants	Systemically healthy individual aged between 18 and 58 years who presented with severe vertical alveolar bone deficiency of partial or completely edentulous areas
Intervention	Autogenous bone grafting
Comparator	Alveolar distraction osteogenesis
Outcome	Bone gain (Radiographic assessment in mm) Bone resorption (Radiographic assessment in mm) Complications Success and Survival rate of the implant

Table 2 Comparative studies between Alveolar Distraction Osteogenesis (ADO) and Autogenous Bone grafting (ABG) for vertical ridge Augmentation in this Review and Meta-analysis

Study	Study years	Study type	Distractor	Type of bone graft	No. of patient		No. of implants	
					ADO	ABG	ADO	ABG
Chiapasco et al. [13]	2007		Intraoral extraosseous distractor (Gebru¨der Martin GmbH & Co. KG)	Onlay, Mandibular ramus	9	8	21	19
Bianchi et al. [14]	2008		3 cases: Track 1.5 mm distractor fixed with 1.5 center-drive screws (KLS Martin, Tuttlingen, Germany) 1 case: Al-Mar with 1.6 screws (Cizeta, Bologna, Italy) 1 case: LactoSorb @resorbable alveolar distraction device with resorbable screws (Walter Lorenz Surgical, Jacksonville, FL)	Inlay, Iliac crest bone graft	5	6	16	21
Uckan et al. [15]	2008			Onlay, Mandibular Ramus	22	14	46	32
Kim et al. [16]	2013		Track 1.5, Gebrüder Martin, Tuttlingen, Germany; 10 mm, 15 mm	Onlay, Mandibular Ramus	14	28	41	61

was performed by two authors independently using Mendeley software. This search strategy was performed independently by two reviewers.

Eligibility Criteria

The focused research question for the systematic review was defined according to PICOs format (Table 1)—Is there any difference in vertical ridge augmentation using distraction osteogenesis and autogenous bone grafting methods?

Inclusion criteria: Randomised controlled trials and Retrospective studies with English language restriction were included.

Exclusion criteria: Case reports, technical reports, animal studies, in vitro studies, and review papers.

Data Extraction

Included studies were subjected to data extraction independently by two reviewers. In the first stage of the data extraction, the following data were collected: author, year of publication, type of study, number of participants in each group, type of distractor used, type of bone graft and the number of implants in each group (Table 2).

In the second stage, the following data were extracted: the site of bone augmentation, the amount of bone gain & resorption, the incidences of complication, the time of implant placement, the number of failed implants, survival

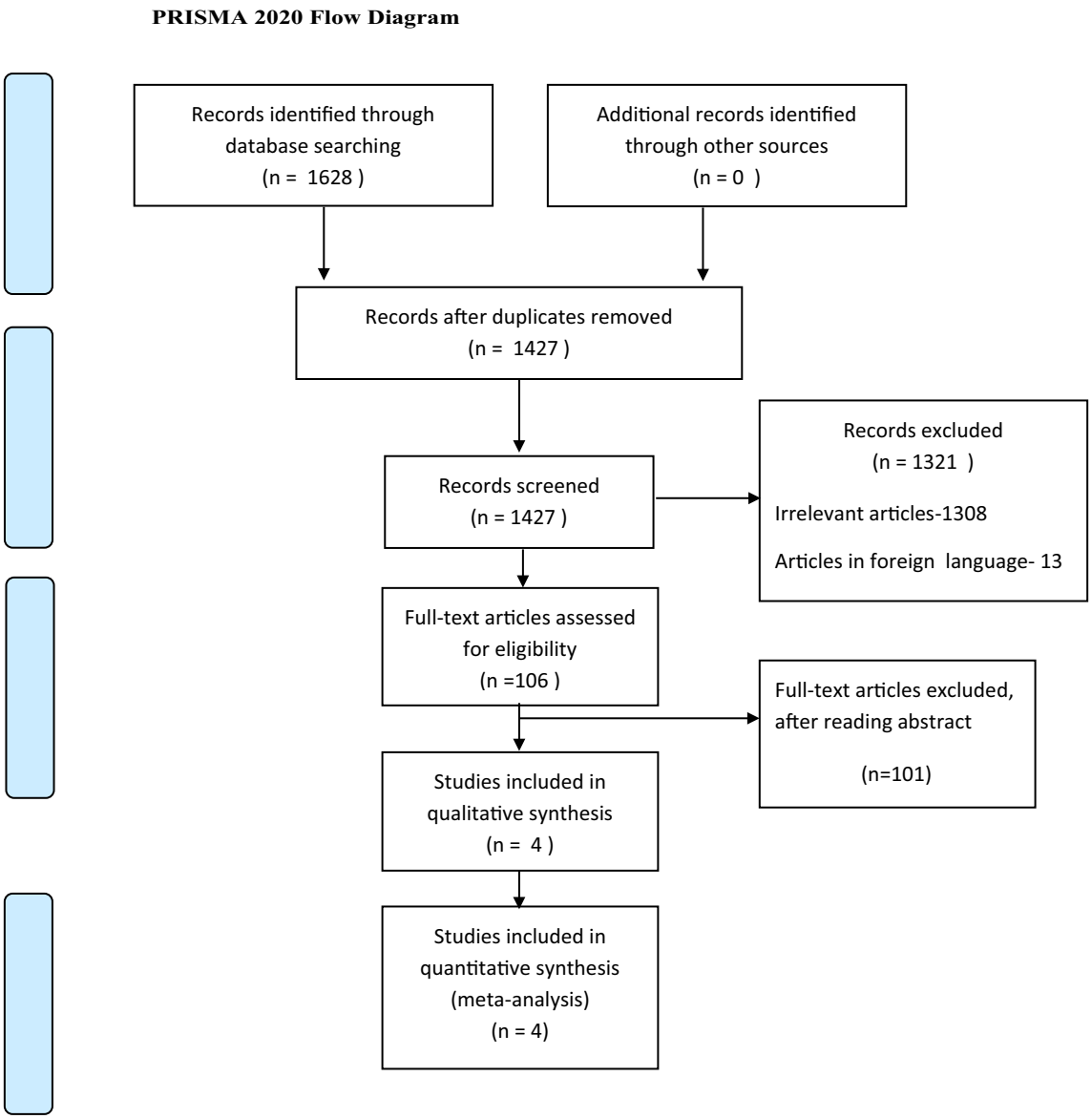

Fig. 1 Risk of Bias assessment of Randomised controlled trials

Table 3 Risk of bias according to ROBINS-I tool for non-randomized studies

Sr. no.	Study id	Confounding bias	Selection bias	Misclassification bias	Bias due to deviation from intended interventions	Bias due to missing data	Bias due to selective reporting of results	Overall bias	Risk of bias
1	Kim et al. [16]	Low risk	Low risk	Low risk	Unclear	Unclear	Low risk	Unclear	Moderate risk

and success rate of implant and the duration of follow up in each group.

Quality Assessment

The risk of bias of each study was evaluated by the two reviewers independently. The risk of bias of clinical trials was assessed using the Cochrane Collaboration risk-of-bias tool in the Cochrane Handbook for Systematic Reviews of Interventions version 5.0.1. With this tool, each study was rated as exhibiting a low, high, or unclear (no information or uncertain) risk of bias (Fig. 1) [10].

The risk of bias of the retrospective study was evaluated using the ROBINS-I assessment tool [11] (Risk of Bias in non-randomised studies- of intervention). The bias due to confounding, in selection of participants, classification of interventions, due to deviation from intended interventions, missing data, measurements of outcomes, in selection of reported results were found to be low (Table 3).

Meta-Analysis

Heterogeneity was assessed using Cochrane's Q and I^2 statistics. Constant continuity corrections of + 1 were performed in case of no events in both test and control groups. Random-effect meta-analysis was performed using the DerSimonian–Laird estimator of variance. As sensitivity analysis, fixed-effect meta-analysis was performed using the Mantel–Haenszel method. SMD and 95% confidence intervals (95% CI) were calculated as effect estimates. Meta-analysis was performed using SPSS v 21.0 (IBM), Epi info v 7.1 (CDC, WHO), Medcalc v 12.5.0.0 (Osteend, Belgium),

RevMan 5.4.1 and graph Pad Prism v. 6.1 and a few online available resources for measuring Heterogeneity and quality checks of individual articles, guidelines like Consort, PRISMA, QUOROM and MOOSE**.**

GRADE Analysis

The quality of evidence for primary outcome was evaluated using The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [12]. Initially, a baseline quality rating was assigned to the evidence and then "downgraded" or "upgraded" that quality rating based on specific characteristics of the included studies. The GRADE guidelines assign an initial baseline rating of "high" quality evidence for experimental human studies and "low" quality to observational studies [12]. This assessment was performed under four domains—risk of bias, inconsistency, indirectness by two independent reviewers.

Publication Bias

Publication bias was evaluated using Funnel Plot. The funnel plot showed symmetry when the studies were analysed indicating no publication bias.

Results

Characteristics of Included Studies

Four [13–16] (three RCTs, one retrospective study) articles were found to meet our criteria in which a sum of 50 patients underwent ADO and 56 patients for ABG with a total of 133 and 124 implants respectively.

Quality Assessment

One out of the three RCTs included were considered as having a high risk of participant and clinician/researcher blinding bias, due to the nature of the study which makes blinding impossible. Quality assessment of

Table 4 Results of GRADE assessment

No. of studies (participants)	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty of the evidence
3 RCT 1 Non-RCT	Serious	Not serious	Not serious	Not serious	Not serious	Moderate

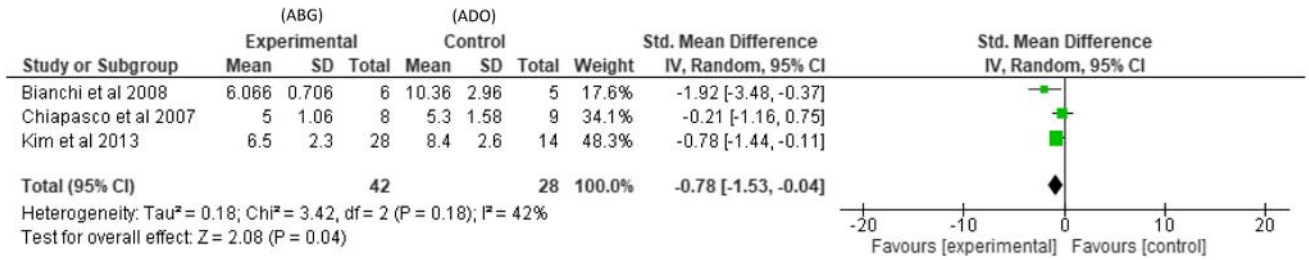

Fig. 2 Forest plot for random effects representing pooled data analysis for bone gain

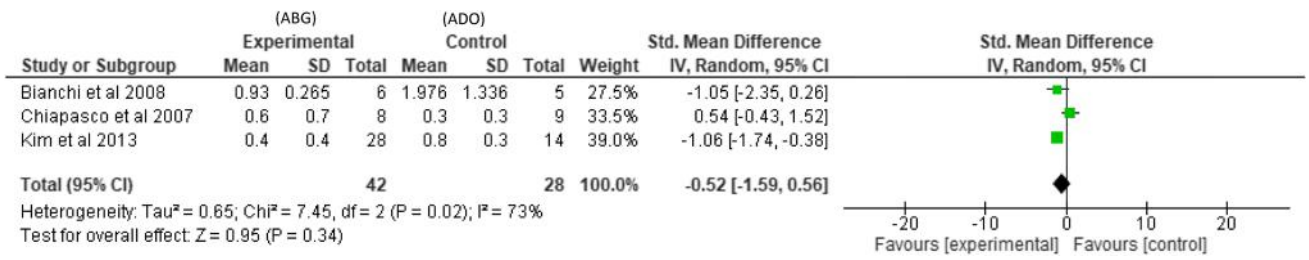

Fig. 3 Forest plot for random effects representing pooled data analysis for bone resorption

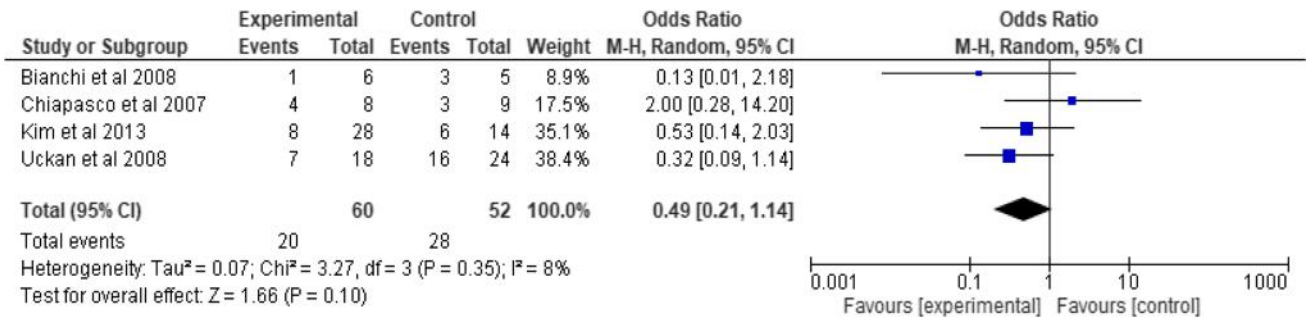

Fig. 4 Forest plot for random effects representing pooled data analysis for complications

non-randomized studies revealed that the overall risk of bias was moderate.

GRADE Analysis

Based on GRADE assessment, the available evidence was of moderate quality (Table 4).

Bone Gain Measured Preoperatively and at the Time of Implant Placement

Although some studies have shown that SMD has crossed 0, i.e. the line of no effect, with 95% CI going below 0 (& negative also) however the total random effects SMD obtained was − 0.78 (95% − 0.06–4 to 1.53). The final SMD favors ABG group (Fig. 2).

Bone Resorption Measured Pre-operatively and at the Time of Implant Placement

The SMD has crossed 0, i.e. the line of no effect, with 95% CI going below 0 (and negative also) however the total random effects SMD obtained was − 0.52 (95% − 1.59 to 0.56). The final SMD slightly favours ABG group. Since line 0 is crossed, the SMD becomes non-conclusive (Fig. 3).

Incidences of Complications

As most of the individual studies, the line of no effect, i.e. Odd's ratio = 1 was crossed and also as seen with 95% CI for each of the studies. However, the summary measure obtained was 0.49 (95% CI 0.21–1.14) also has crossed 1 on either side, it can be concluded that there is no additional difference of the test intervention over the control (Fig. 4).

Discussion

Dental implants are considered the best option for replacement of missing teeth. The placement and survival of dental implants is largely affected by the amount of residual bone. Over the years, multiple options such as autologous grafts, allografts and xenografts have been used with or without guided bone regeneration.

ABG is the gold standard in craniofacial bone grafting as it is biocompatible, carries no risk of cross infection and is inexpensive [17]. Multiple sites in the human body offer cancellous as well as cortical bone in variable volumes and shapes which makes ABG a versatile option. It requires only a single surgery and does not require patient compliance. However it is not without disadvantages such as donor site morbidity, limited quantity of graft, high resorption rates and requires complete soft tissue coverage for success which may necessitate harvesting soft tissue as well [18, 19].

The introduction of ADO in the 90 s has done away with some of these disadvantages and is therefore being used as an alternative nowadays. ADO involves the placement of a distractor device and creating a transport bone segment which is slowly moved away from the host bone followed at the rate of 1 mm per day after a period of latency to stimulate regeneration of bone and soft tissue. Its primary advantages are the fact that a second donor site is not needed and risk of graft rejection is completely eliminated. In addition, its ability to regenerate soft tissue simultaneously has made it a popular choice over the years [20]. Disadvantages of ADO include the higher costs, second surgery to remove the device, complications related to the failure of the device, improper planning, fracture of transport segment, etc. [21]. A minimum of 6-7 mm of basal bone is the basic requirement for DO [22]. Success in ADO is heavily reliant on the patient's co-operation.

There is no consensus on which of these two methods is superior for bone augmentation prior implant placement.

Bone Gain

ADO has been found to be capable of providing a mean increase of 7–8.2 mm height while ABG reportedly can result in 4.75–5.75 mm vertical bone gain with onlay grafts at the end of 6 months [23, 24]. In this SR bone gain was found to be lesser in ABG group than in ADO group which was similar to RCTs by Kim et al. [16], Bianchi et al. [14] and Chiapasco et al [13]. The type of bone used influences the amount of bone gain. Kim et al [16] and Chiapasco et al. [13] used cortical bone in block and particulated form while Bianchi et al [14] used cortico-cancellous bone from the iliac crest. Yun et al. compared ADO with inlay and onlay and found that inlay graft was superior to ADO in terms of bone gain but with onlay it was similar [8]. Lower bone gain in this SRMA could be due to the fact that majority of the studies used onlay grafts.

Bone Resorption

Bone resorption showed no significant difference between the groups in this SRMA. There was no uniformity in the type of graft used and the site of grafting both of which can influence the resorption. Resorption was higher in the ABG group in all the studies except Bianchi et al. [14] which saw higher resorption in ADO group. Bianchi et al. [14] used inlay grafts while others used onlay graft. These findings support that of Yun at el [8] which says inlay grafts are superior to only grafts.

Yun et al [8] in a SRMA in 2016 found no significant difference in the resorption rate in between the two groups which is similar to our findings, however they have included the GBR technique which was excluded in ours. Toledano et al. [9] in their SR reported more resorption in ABG but they had included only two studies by Bianchi et al. [14] and Chiapasco et al. [13] The addition of the study by Kim et al. [16] with a large sample size is the reason for the difference in results.

Complications

According to the results of this study the incidence major and minor complication were not different between groups. Bianchi et al. [14], Uckan et al. [15] and Kim et al. [16] saw more incidences of complications with ABG technique while Chiapasco et al. [13] saw more complications in ADO group. Lingual inclination of distracted segment was the most common complication seen in the ADO group and local infection was most common in the ABG group. Majority of the complications in both groups across studies were minor and easily resolved.

Implant Survival and Success Rate

A meta-analysis for the success and survival rate of implants could not be carried out due to the differences in the timing and duration of follow up in the studies. Chiapasco et al. [13] and Bianchi et al. [14] reported a 100% survival rate in both groups. Uckan et al. [15] reported a higher survival rate 93.7% in ABG group, compared with ADO and Kim et al. [13] reported higher survival rate in ADO group 97.3%.

The success rate of implant was higher in ADO group in studies by Chiapasco et al. [13] and Kim et al. [16] with values 94.7% and 92.7%, respectively, whereas Bianchi et al. [14] reported lower success rate in ADO with value 93.7%.

Thus, no relevant differences between studies were found for implant survival and success rates.

Limitations

Given the availability of only a handfull RCTs with small sample sizes, the meta-analysis did not give any conclusive result with regards to bone resorption and incidences of complications. The studies also lack information on the size of defect and the degree of horizontal deficiency. There was no standardisation of the type of bone, site of bone harvesting and type of distractor used. The type of implants used, whether coated or non-coated and the duration of follow up was also not mentioned. The inclusion of only 4 studies and two studies with high risk of bias and a small sample size limits the results of this SR. There is a clear need for well-designed RCTs with larger sample sizes and longer follow-up period to examine the long-term fate of implants placed in augmented bone.

Conclusion

Our SRMA showed that bone gain was greater in ADO whereas it was statistically inconclusive in terms of bone resorption and incidences of complications. Considering the limitations of our systematic review as mentioned before the authors interpret the results of the study with caution. The surgeon must choose the treatment in accordance with the patient's desires and opinions, considering the risks and benefits of each decision. Thus, the choice of treatment must be made according to the clinical status of the patient, while taking into consideration the indications of each method.

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Declarations

Conflict of interest The authors declare that there was no conflict of interest during the elaboration of this study.

Ethical Approval Not applicable.

Human and Animal Rights Statement Not required; the study did not involve human subjects.

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