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Systematic Review and Meta-Analysis
Orthognathic Surgery

Orthodontic camouflage versus orthodontic-orthognathic surgical treatment in class II malocclusion: a systematic review and meta-analysis

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Abstract. This systematic review was performed to compare dental, skeletal, and aesthetic outcomes between orthodontic camouflage and surgical-orthodontic treatment, in patients with a skeletal class II malocclusion and a retrognathic mandible who have already finished their growth period. A literature search was conducted, and a modified Downs and Black checklist was used to assess methodological quality. The meta-analysis was conducted using the DerSimonian–Laird random-effects method to obtain summary estimates of the standardized mean differences and corresponding 95% confidence intervals. Nine articles were included in the qualitative synthesis and seven in the meta-analysis. The difference between treatments was not statistically significant regarding SNA angle, linear measurement of the lower lip to Ricketts' aesthetic line, convexity of the skeletal profile, or the soft tissue profile excluding the nose. In contrast, surgical-orthodontic treatment was more effective with regard to ANB, SNB, and ML/NSL angles and the soft tissue profile including the nose. Different treatment effects on overjet and overbite were found according to the severity of the initial values. These results should be interpreted with caution, due to the limited number of studies included and because they were non-randomized clinical trials. Further studies with larger sample sizes and similar pre-treatment conditions are needed.

Key words: meta-analysis; class II malocclusion; adults; orthodontic camouflage; surgical-orthodontic treatment.

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For patients with a skeletal class II malocclusion who are still in the growth period, growth modification should be considered as the first option for the correction of the underlying skeletal deformity. However, if the patient has already completed their growth, it is necessary to take other treatment approaches into account, such as orthodontic camouflage or orthodontic-surgical treatment. The option of no treatment should also be respected[1–3].

In orthodontic camouflage treatment, the aim is to mask the skeletal discrepancy through dental compensations. When extractions are required, they are generally done in the upper arch (first pre-molars) to correct the protrusion of the incisors. In addition, the use of functional appliances normally used in growth modification, but instead used in adult patients to change the dental position, has been reported[2–5].

Orthodontic-surgical treatment is intended to correct the underlying skeletal class II deformity, and in most surgical patients, only mandibular advancement surgery is required to correct mandibular retrognathia. However, some patients require superior repositioning of the maxilla or bimaxillary surgery (maxilla up and mandible forward)[6]. The two single-jaw procedures are considered very stable, whereas the combination of maxillary and mandibular surgery is stable only with rigid fixation[7].

According to the available literature, there are no clear guidelines on the best treatment approach for adult patients, nor have there been any previous systematic reviews on this subject. Therefore, the aim of this systematic review was to assess the methodological quality, summarize the findings, and perform a meta-analysis of published trials that have investigated which approach (surgical-orthodontic treatment or orthodontic camouflage treatment) results in the largest improvement in dental, skeletal, and aesthetic measurements in patients with a skeletal class II malocclusion who have already finished their growth period.

Materials and methods

Protocol and registration

This systematic review and meta-analysis was conducted according to the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[8], and the protocol was registered in the International Prospective Register of Systematic Reviews, PROSPERO (http://www.crd.york.ac.uk/PROSPERO, protocol CRD42016042842).

Eligibility criteria

The acronym PICOS (population, intervention, comparison, outcomes, study design) was used to establish primary inclusion criteria for the studies[9]: (1) Population: patients with a skeletal class II malocclusion who have already finished their growth period or for whom significant growth is not expected to occur; (2) Intervention: surgical-orthodontic treatment; (3) Comparison: orthodontic camouflage treatment; (4) Outcome: dental, skeletal, and aesthetics measurements; (5) Study type: non-randomized clinical trials to assess therapeutic interventions.

The exclusion criteria were craniofacial anomalies, transverse discrepancies, skeletal asymmetries, and tooth size discrepancies.

Information sources, search strategy, and study selection

The search included the following electronic databases: Cochrane Library (1898 to September 2016), PubMed (1809 to September 2016), LILACS (1982 to September 2016), Scopus (1823 to September 2016), and Web of Science (1900 to September 2016). Unpublished literature was also considered in this systematic review through a search of ClinicalTrials.gov (http://www.clinicaltrials.gov) and the International Standard Registered Clinical/soCial sTudy Number ISRCTN (http://www.isrctn.com) (Supplementary Material, Appendix A).

Before beginning the search in the selected databases, the search strategy was discussed between three investigators (RR, TP, and MP). The study selection was then performed independently, in duplicate, and in an unblended standardized manner by two reviewers (RR and TP). Following the removal of duplicates, the reviewers (RR and TP) screened all articles by title and abstract. They then reviewed the full-text publications to confirm final eligibility criteria. Disagreements were resolved by consensus between the two reviewers; a third author (MP) was involved when necessary. During the screening process, the authors of the studies under analysis were contacted as required.

Data items and collection

A data extraction sheet was developed. One of the reviewers (RR) extracted the data from the studies that were considered eligible and the second reviewer (TP) checked the extracted data. Disagreements were resolved by discussion between the reviewers; when necessary, a third author (MP) was consulted. Further information and clarifications were requested from the authors of the studies when necessary.

The following study characteristics were required: population (total sample size, skeletal malocclusion, age, sex); intervention, i.e. surgical orthodontic treatment (sample size, type of surgery, with/without mentoplasty, with/without extractions, surgical technique/type of fixation); comparison, i.e. orthodontic camouflage treatment (sample size, method, with/without extractions); outcomes (skeletal, dental, and aesthetic measurements); study type (non-randomized clinical trials). The skeletal measurements considered were the SNA angle (sella–nasion–A point), SNB angle (sella–nasion–B point), ANB angle (A point–nasion–B point), and ML/NSL angle (mandibular line/nasion–sella line), which is the angle between the anterior cranial base and the mandibular plane. Dental measurements were overjet and overbite. Aesthetic measurements included the LL–E-line (the distance between Ricketts' aesthetic line (E-line) and the lower lip), N–A–Pog angle (nasion–A point–pogonion), N′–Sn–Pog′ angle (soft tissue nasion–subnasale–soft tissue pogonion), and N′–Pn–Pog′ angle (soft tissue nasion–nose tip–soft tissue pogonion).

Risk of bias in individual studies

This systematic review used a modification of the Downs and Black checklist for the assessment of the methodological quality of non-randomized studies. This assessment was done independently and in duplicate by two investigators (RR and TP). Once again, any disagreements were resolved through discussion with a third author (MP).

The original checklist consists of 27 items, which are distributed between five sub-scales (maximum score of 32 points): quality of reporting (10 items), external validity (3 items), internal validity in terms of bias (7 items), internal validity in terms of confounding (selection bias; 6 items), and statistical power (1 item)[10]. All original items were used except for the 27th item, for which a simplification of the question was formulated: ''Did the study do a power analysis or a sample size estimation?'' The answer was 'yes' (5 points) if the study had a high statistical power and/or estimated sample size (representative sample), 'partially' (3 points) if the study had a lower statistical power and/or estimated sample size (non-representative sample), or 'no' (0 points) if the study did not do any power analysis and/or sample size estimation. The study quality was scored as high (total score 25–32), moderate (total score 17–24), or low (total score 0–16).

Summary of measurements and synthesis of results

The meta-analysis was undertaken using STATA version 11.2 statistical software

(StataCorp, College Station, TX, USA). The DerSimonian–Laird random-effects method was used to obtain summary estimates of the standardized mean differences (SMD) and the corresponding 95% confidence intervals (95% CI). Additionally, the following were extracted from each study to obtain the SMD: the sample size and the mean and standard deviation, for pre-treatment and post-treatment orthodontic camouflage and orthodontic-surgical treatment. Heterogeneity between studies was quantified using the I^2 statistic, with values of 25% corresponding to low, 50% corresponding to moderate, and 75% corresponding to high heterogeneity.

Risk of bias across studies and additional analysis

Publication bias was assessed by visual inspection of the funnel plots and Egger's regression asymmetry tests. A *P*-value of <0.05 was considered to reflect statistical significance.

Sensitivity analyses were performed in the case of publication bias or in the presence of other sources of heterogeneity.

Results

Study selection

The PRISMA guidelines were employed in this systematic review (Fig. 1). A total of 1688 articles were initially identified in the electronic databases. Internal and external duplicates were then removed with EndNote X7 ($n = 608$) and by subsequent manual screening to identify remaining duplicates ($n = 65$). A total of 1015 potentially relevant articles were screened based on their title and abstract, of which 940 records were excluded. The final 75 articles were assessed for eligibility through full-text evaluation, after which 66 were excluded (Supplementary Material, Appendix B). Thus, nine studies were included in the qualitative synthesis[1–5,11–14].

In order to proceed with the quantitative synthesis, three studies were excluded[1,11,12]: Mihalik et al.[1] did not report the post-treatment mean and standard deviation, Cassidy et al.[11] did not report the pre- and post-treatment standard deviation, and Bollen and Hujoel[12] only considered pre-treatment values and did not use a comparable study design. The study by Kinzinger et al.[3] divided camouflage orthodontic treatment into two subgroups (group 1: extractions; group 2:

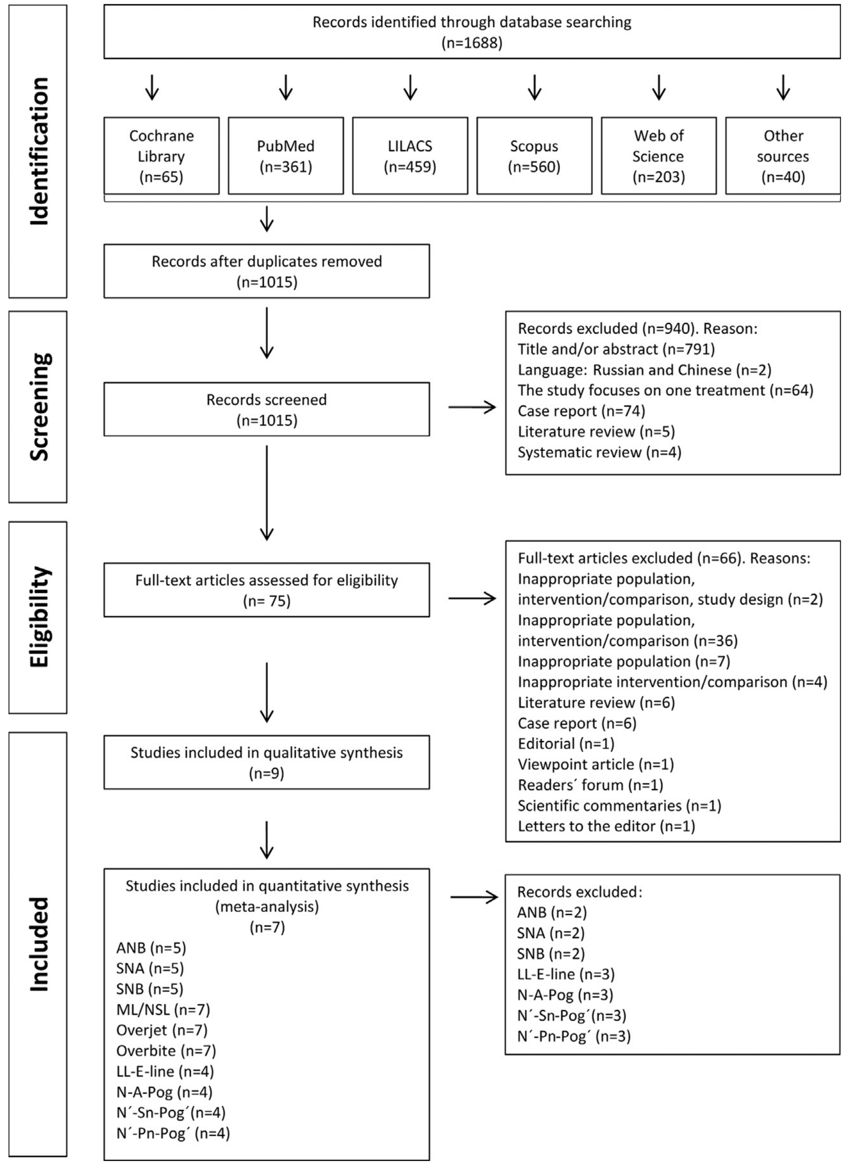

Fig. 1. PRISMA flow diagram.

fixed appliances), with two different estimates of SMD. Therefore, seven studies were included in the meta-analysis.

Study characteristics

The study characteristics are summarized in Table 1; the full version is available in the Supplementary Material (Appendix C). There were variations in the total sample size (range 12–182 patients), age (range 12.7–31.9 years), and sex (482 female, 149 male) among the studies included. All included studies compared surgical-orthodontic treatment (352 patients) with camouflage treatment (258 patients). However, the camouflage method was not always the same: 193 patients had extractions/non-extraction treatment and 65 patients had camouflage with fixed appliances (Forsus, Herbst, or Forestadent). The nine studies included in the qualitative synthesis used cephalometric analysis to evaluate dental, skeletal, and/or aesthetic parameters, and all were considered retrospective, non-randomized clinical trials.

Risk of bias within studies

For the included studies, the scores of the Downs and Black checklist are provided in the Supplementary Material (Appendix D). With regard to the qualitative synthesis, four studies presented moderate quality[1,11–13], and five studies were low quality[2–5,14]. However, three studies of moderate quality were eliminated from the meta-analysis for the reasons stated above[1,11,12]. Consequently, only one study

Table 1. Population, intervention, comparison, outcome, and study design of studies included in the qualitative synthesis (abbreviated version).

Study	Population	Interventions	Comparators	Outcomes	Study design
Kabbur et al. (2012)[4]	12 patients	6 patients Mandibular advancement	6 patients OC2: Forsus appliance	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Kinzinger et al. (2009)[3]	60 patients (33 F, 27 M) Mandibular advancement: 25.7 years OC1: 18.7 years OC2: 17.6 years	20 patients Mandibular advancement	20 patients OC1 (dental extractions) 20 patients OC2 (Herbst or Forestadent appliance)	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Chaiyongsirisern et al. (2009)[5]	32 patients (23 F, 9 M) Mandibular advancement: 24 years OC2: 22 years	16 patients Mandibular advancement	16 patients OC2 (Herbst appliance)	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Ruf and Pancherz (2004)[2]	69 patients (57 F, 12 M) Mandibular advancement: 26 years OC2: 21.9 years	46 patients Mandibular advancement	23 patients OC2 (Herbst appliance)	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Mihalik et al. (2003)[1]	182 patients (157 F, 25 M) Mandibular advancement: 29 years Maxillary impaction: 23 years Bimaxillary surgery: 27 years OC1: 28.6 years Without treatment: 29.9 years	118 patients[a] Mandibular advancement Maxillary impaction Bimaxillary surgery	31 patients OC1 (dental extractions) 33 patients without treatment[a]	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Bollen and Hujoel (1994)[12]	44 patients (44 F) Surgical-orthodontic treatment: 25.2 years OC1: 18.1 years	23 patients Surgical-orthodontic treatment	21 patients OC1 (dental extractions, yes/no)	Dental and skeletal evaluation	Retrospective NRCT
Cassidy et al. (1993)[11]	53 patients (44 F, 9 M) Mandibular advancement, bimaxillary surgery: 31.9 years OC1: 27.6 years	26 patients Mandibular advancement, bimaxillary surgery	27 patients OC1 (dental extractions, yes/no)	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Proffit et al. (1992a)[13]	90 patients (63 F, 27 M) Mandibular advancement: 30.5 years OC1: 22.2 years	57 patients Mandibular advancement	33 patients OC1 (dental extractions, yes/no)	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT
Proffit et al. (1992b)[14]	101 patients (61 F, 40 M) Mandibular advancement, maxillary impaction, bimaxillary surgery: 15.2 years OC1: 13.9 years OC1 failure: 12.7 years	40 patients Mandibular advancement, maxillary impaction, bimaxillary surgery	40 patients OC1 (dental extractions, yes/no) 21 patients OC1 failure (dental extractions, yes/no)	Dental, skeletal, and aesthetic evaluation	Retrospective NRCT

F, female; M, male; NRCT, non-randomized clinical trial; OC1, orthodontic camouflage (method 1: with/without extractions); OC2, orthodontic camouflage (method 2: with fixed appliances).
[a] Mihalik et al. (2003) used sample sizes from other studies.

in the quantitative synthesis presented moderate quality[13].

The quality of reporting was usually clearly described in the studies, and the majority of the articles obtained a good score for this category (Supplementary Material, Appendix D). However, the external validity in these studies was low, for two main reasons: the studies did not evaluate the representativeness of the population, and the place where the sample was treated was not always representative of the population. The internal validity in terms of bias was properly assessed for most items. However, only two studies tried to blind the assessors[11,13], and the majority of the studies ignored differences in follow-up[2–4,11–14]. The internal validity in terms of confounding (selection bias) was low in all included studies because they were non-randomized clinical trials. Finally, in general, the studies did not consider a power analysis or sample size estimation.

Results of individual studies, meta-analysis, and additional analysis

The SNA, SNB, and ANB angles were used to determine the skeletal sagittal jaw relationship. The differences between treatments were not statistically significant for the SNA angle (SMD 0.04, 95% CI −0.37 to 0.44; $I^2 = 0\%$; P = 0.995; *n* = 5). In contrast, surgical-orthodontic treatment was more effective than orthodontic camouflage for the ANB angle (SMD −1.04, 95% CI −1.38 to −0.70; $I^2 = 0\%$; P = 0.816; *n* = 5) and the SNB angle (SMD −0.51, 95% CI −0.86 to −0.16; $I^2 = 0\%$; P = 0.974; *n* = 5) (Fig. 2).

Two sensitivity analyses were performed for the ANB angle: the first was restricted to studies in which significant growth was not expected to occur, therefore excluding the study by Proffit et al.[14] (SMD −0.88, 95% CI −1.37 to −0.39; $I^2 = 0\%$; P = 0.849; *n* = 4); the second was a subgroup analysis according to the orthodontic camouflage method (method 1: SMD −1.17, 95% CI −1.58 to −0.77; $I^2 = 0\%$; P = 0.966; *n* = 2; method 2: SMD −0.71, 95% CI −1.33 to −0.09; $I^2 = 0\%$; P = 0.976; *n* = 3). Neither of these analyses provided a different overall result.

For the SNA angle, a sensitivity analysis was performed in which studies were restricted to those only using method 2 (SMD −0.01, 95% CI −0.45 to 0.44; $I^2 = 0\%$; P = 1.000; *n* = 4). The same was done for the SNB angle (SMD −0.46, 95% CI −0.86 to −0.06; $I^2 = 0\%$; P = 0.974; *n* = 4). The results did not differ from the overall results.

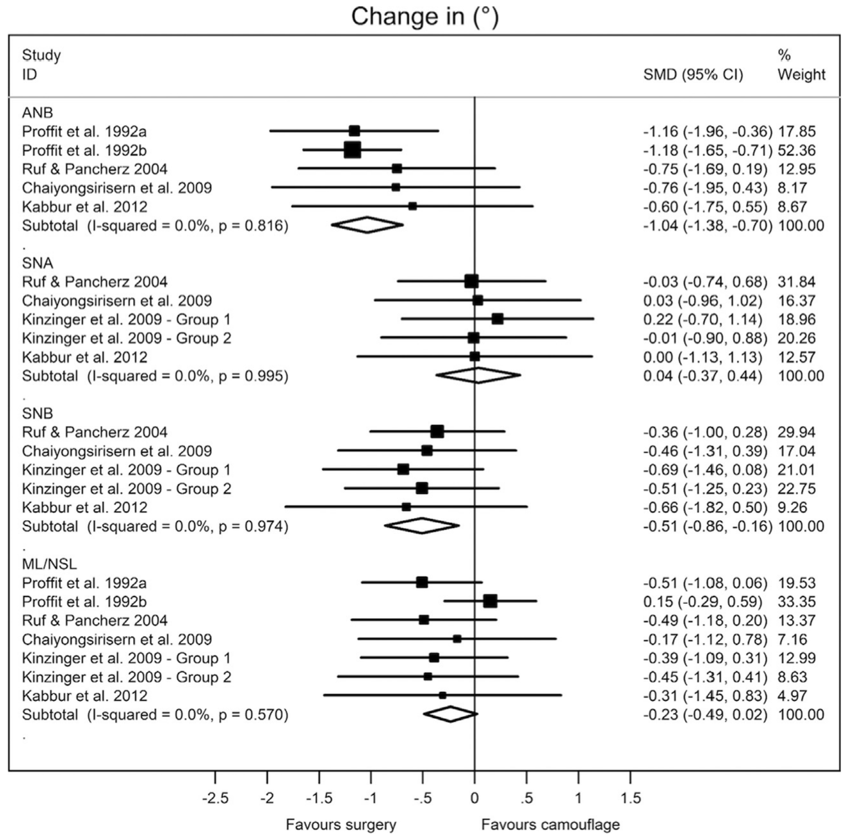

Fig. 2. Forest plot of skeletal sagittal measurements: ANB, SNA, SNB, and ML/NSL angles.

The ML/NSL angle was used to determine the skeletal vertical jaw relationship. The meta-analysis of this measure did not show any difference between treatments (SMD −0.23, 95% CI −0.49 to 0.02; $I^2 = 0\%$; P = 0.570; *n* = 7) (Fig. 2). After performing a sensitivity analysis restricted to studies that only used mandibular

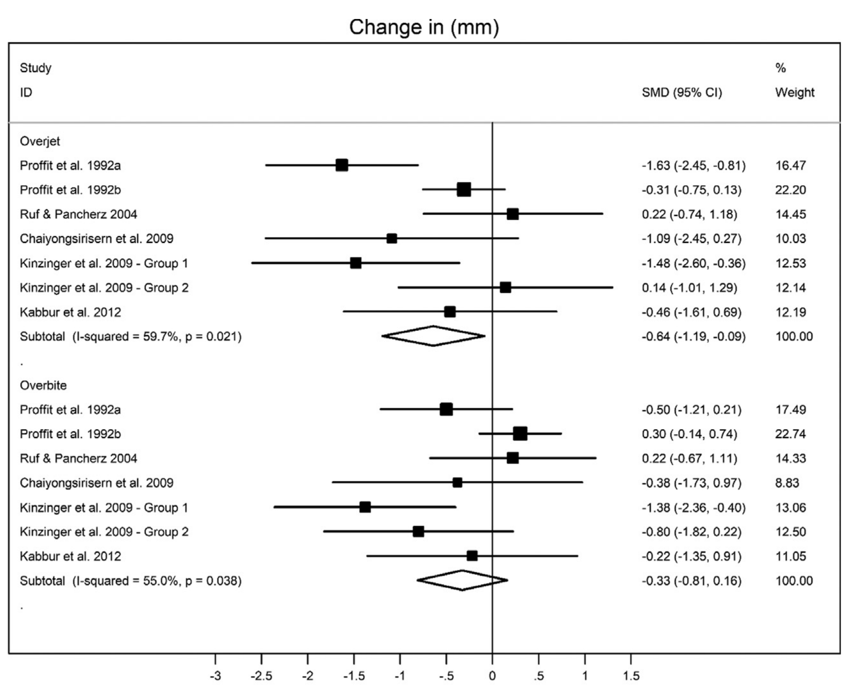

Fig. 3. Forest plot of dental measurements: overjet (mm) and overbite (mm).

advancement surgery and where significant growth was not expected to occur, surgical-orthodontic treatment was considered more effective in terms of the ML/NSL angle (SMD −0.42, 95% CI −0.73 to −0.11; I^2 = 0%; P = 0.994; *n* = 6).

The dental measurements of overjet and overbite (in millimetres) showed different treatment effects according to the severity of the initial values.

For overjet, surgical-orthodontic treatment was more effective than orthodontic camouflage (SMD −0.64, 95% CI −1.19 to −0.09; I^2 = 59.7%; P = 0.021; *n* = 7) (Fig. 3). However, as moderate heterogeneity was found, a sensitivity analysis was conducted. Initially restricted to studies in which significant growth was not expected to occur (SMD −0.73, 95% CI −1.43 to −0.03; I^2 = 60.6%; P = 0.027; *n* = 6), the results were not different from the overall results, nor was heterogeneity reduced. In a posterior subgroup analysis, two groups were identified according to the pre-treatment condition, with a cut-off point of −0.5 (Fig. 4A). In the less than or equal to −0.5 subgroup, surgical-orthodontic treatment was more effective than orthodontic camouflage (SMD −1.48, 95% CI −2.08 to −0.89; I^2 = 0%; P = 0.802; *n* = 3). In the greater than −0.5 subgroup, differences between treatments were not statistically significant (SMD −0.18, 95% CI −0.56 to 0.20; I^2 = 0%; P = 0.525; *n* = 3) (Fig. 4B). Finally, the same subgroup analysis was performed excluding the study by Proffit et al.[14]: in the greater than −0.5 subgroup, the results (SMD 0.19, 95% CI −0.55 to 0.93; I^2 = 0%; P = 0.917; *n* = 2) were not different from those obtained before.

For overbite, differences between treatments were statistically negligible (SMD −0.33, 95% CI −0.81 to 0.16; I^2 = 55%; P = 0.038; *n* = 7) (Fig. 3). Once again, moderate heterogeneity required a sensitivity analysis restricted to studies in which significant growth was not expected to occur. The overall results changed: surgical-orthodontic treatment was considered more effective in terms of overbite, and heterogeneity was reduced (SMD −0.51, 95% CI −0.95 to −0.07; I^2 = 19.1%; P = 0.289; *n* = 6). A subgroup analysis was also performed using a cut-off point of −0.1, which was determined on the basis of the pre-treatment condition (Fig. 4A). In the less than or equal to −0.1 subgroup, surgical-orthodontic treatment was more effective than orthodontic camouflage (SMD −0.80, 95% CI −1.31 to −0.30; I^2 = 1.5%; P = 0.362; *n* = 3), and in the greater than −0.1 subgroup, differences between treatments were not statistically significant (SMD 0.23, 95% CI −0.15 to 0.61; I^2 = 0%; P = 0.643; *n* = 3) (Fig. 4C). Finally, the same subgroup analysis was performed excluding the study of Proffit et al.[14] for the greater than −0.1 subgroup, and the results (SMD 0.04, 95% CI −0.71 to 0.78; I^2 = 0%; P = 0.468; *n* = 2) were not different from those obtained before.

For the LL–E-line measurement (in millimetres), the meta-analysis showed that the differences between treatments were not statistically relevant (SMD −0.04, 95% CI −0.45 to 0.37; I^2 = 0%; P = 0.562; *n* = 4) (Fig. 5). A sensitivity analysis restricted to studies that only used method 2 was performed (camouflage with fixed appliances, either Herbst or Forestadent), and the results (SMD −0.21, 95% CI −0.69 to 0.27; I^2 = 0%; P = 0.864; *n* = 3) did not differ from the overall results.

The N–A–Pog measurement was used to evaluate skeletal profile convexity and the N′–Sn–Pog′ and N′–Pn–Pog′ measurements were used to determine the soft tissue profile convexity. The meta-analysis

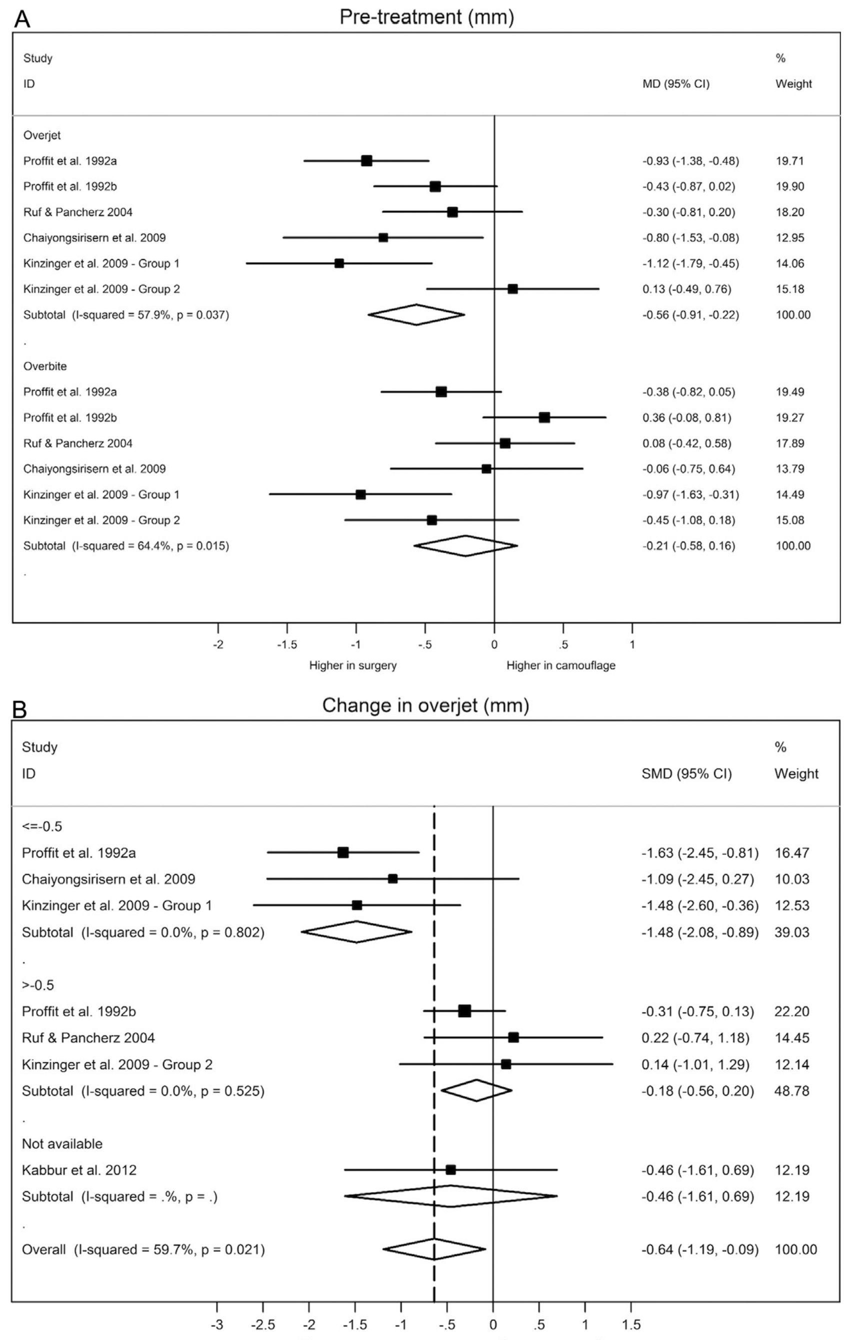

Fig. 4. Kaplan–Meier curve of 5-year overall survival with respect to nodal status.

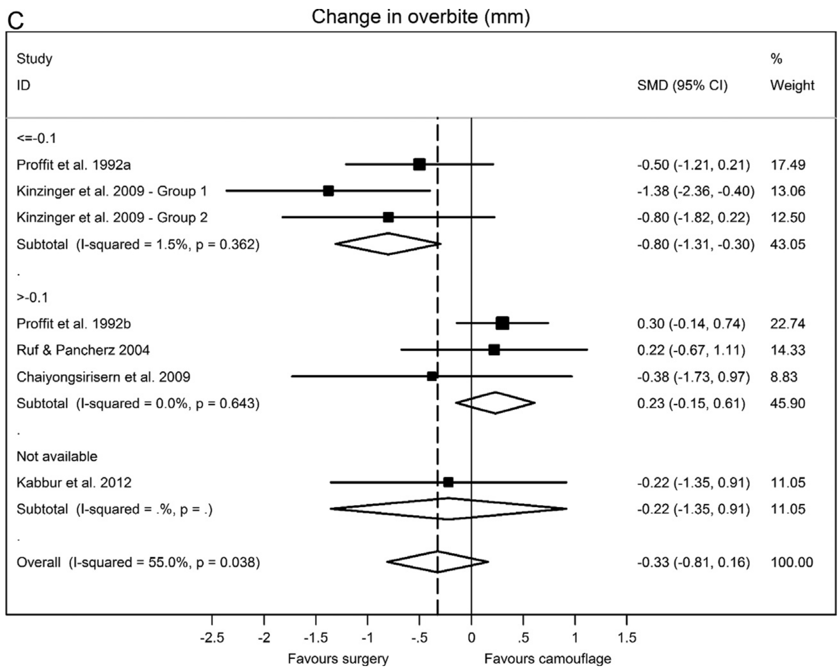

Fig. 4. (*Continued*).

showed that the differences between treatments were not statistically significant for N–A–Pog (SMD −0.30, 95% CI −0.67 to 0.06; $I^2 = 0\%$; P = 0.824; $n = 4$) and N′–Sn–Pog′ (SMD −0.36, 95% CI −0.73 to 0.01; $I^2 = 0\%$; P = 0.984; $n = 4$). However, surgical-orthodontic treatment was more effective than orthodontic camouflage with regard to N′–Pn–Pog′ (SMD −0.48, 95% CI −0.87 to −0.10; $I^2 = 0\%$; P = 0.892; $n = 4$)

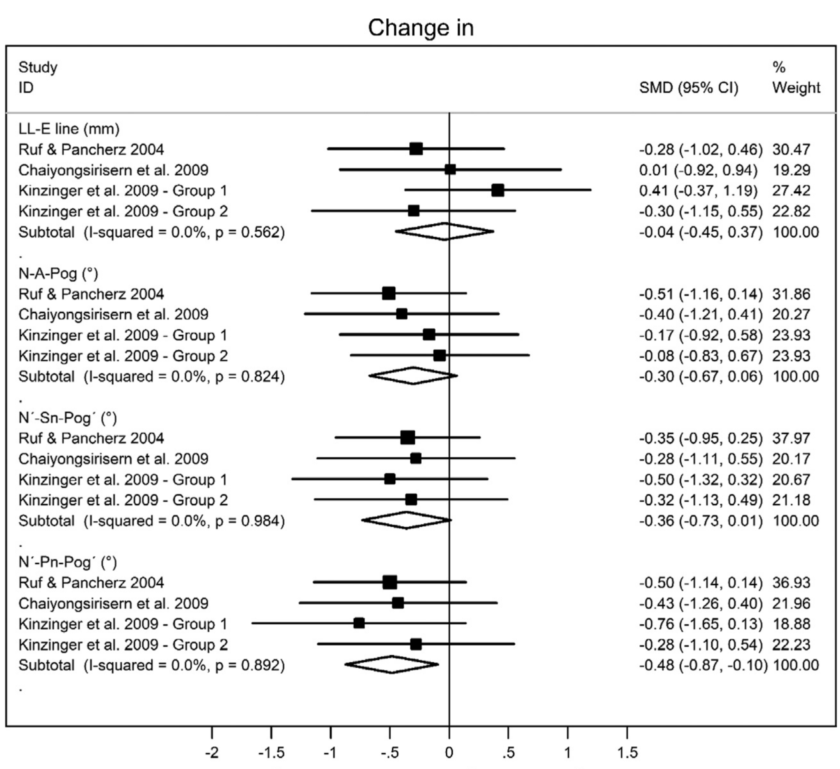

Fig. 5. Forest plot of aesthetic measurements: LL–E-line (mm); and skeletal and soft tissue profile measurements: N–A–Pog, N′–Sn–Pog′, and N′–Pn–Pog′ angles.

(Fig. 5). For these three measurements, sensitivity analyses restricted to studies that only used method 2 (camouflage with fixed appliances, either Herbst or Forestadent) were performed. The results were not different from the overall results in the case of N–A–Pog (SMD −0.35, 95% CI −0.77 to 0.08; $I^2 = 0\%$; P = 0.689; $n = 3$) and N′–Sn–Pog′ (SMD −0.32, 95% CI −0.74 to 0.09; $I^2 = 0\%$; P = 0.991 $n = 3$). However, for N′–Pn–Pog′, the results (SMD −0.42, 95% CI −0.85 to 0.01; $I^2 = 0\%$; P = 0.918; $n = 3$) were different from the overall result, indicating that the differences between treatments were not statistically relevant.

Risk of bias across studies

In general, Egger's regression asymmetry tests indicated no publication bias, except for the ANB angle which had a borderline result ($P = 0.047$) (Supplementary Material, Appendix E).

Discussion

This systematic review with meta-analysis compared orthodontic camouflage treatment and surgical-orthodontic treatment. The qualitative synthesis included nine studies and the quantitative synthesis included seven. The search was very extensive and included a broad range of electronic databases. Thus, this low yield should encourage further research on the subject, in order to overcome the limitations identified in the systematic review and meta-analysis.

Ideally, this systematic review would have included only randomized controlled trials. However, there are ethical questions that need to be considered due to the nature of the treatments. First, in a randomized study, patients who fulfilled the eligibility criteria would be randomly allocated to either surgical-orthodontic treatment or orthodontic camouflage treatment. Unfortunately, this is not a viable approach, because the patients have the right to know which treatment will be performed and furthermore they should also have an active role in the decision process. Ethically, it would not be acceptable to proceed with orthognathic surgery without obtaining prior informed consent. Second, obtaining a control group would be a complex process in this case: patients would have to complete the orthodontic study and then choose not to undergo any intervention, while knowing that they need treatment. Furthermore, even if pre-treatment lateral teleradiography of the head has been performed, it would not be ethical to submit the patient to sequential cephalometric radiographs without treatment[15–17].

All of the studies included were classified as retrospective studies. Had they been prospective in nature, there would have been the advantage of the patients being followed from beginning to end, with the variables of interest controlled from the outset. However, prospective studies have higher costs and a longer duration. Nevertheless, when the study is retrospective, the authors should always attempt to homogenize the initial sample in order to have two groups with similar pre-treatment characteristics. In this systematic review, only two of the studies included tried to standardize pre-treatment variables[3,11].

The Herbst, Forsus, and Forestadent devices, also known as functional appliances, are usually used in young patients to modify growth[18–21]. However, according to the literature, they can also be useful in patients who have already completed their growth period in order to change mainly dental positions. Although skeletal modifications are not expected in adult patients to the same extent, it has been reported that these appliances can stimulate condylar growth and remodelling of the glenoid fossa[2–5]. The present authors propose that the term 'functional appliance' be used exclusively in relation to patients who are still in the growth period and that when used for adult patients, this form of treatment be referred to as a method of orthodontic camouflage treatment. The term 'functional appliance' was taken into account during the research phase of the present study due to its widespread use, in order to include as many relevant studies as possible. The study by Kabbur et al. appears to be the only one described in the literature that has compared the efficacy of the Forsus appliance with surgical-orthodontic treatment in adult patients[4]. This appliance is generally used as a functional appliance in the growth phase. However, in this study it was used only in adult patients. Therefore, to determine whether the Forsus appliance is really a valid alternative to surgical-orthodontic treatment, more studies with better methodological quality and with larger sample sizes are necessary.

The study by Cassidy et al. created a decision tree and, on final balance, orthodontic treatment was found to be more favourable than surgical-orthodontic treatment[11]. However, surgical-orthodontic treatment as performed nowadays would probably present a similar or even higher final balance, since the complications and risks of orthognathic surgery have been minimized[22–24]. The meta-analysis of Verweij et al. evaluated the most frequent surgical complications in patients requiring mandibular surgery with the bilateral sagittal split osteotomy (BSSO): a bad split occurred in 2.3% of patients, a postoperative infection occurred in 9.6%, it was necessary to remove the osteosynthesis material in 11.2%, and there were neurosensory disturbances in the lower lip in 33.9% of the patients[25]. Therefore, the patient should be informed of the inherent risks of orthognathic surgery.

Future studies investigating the limit for each measurement between orthodontic camouflage treatment and surgical-orthodontic treatment would be of interest. It would be necessary to define a standard cut-off point for success for each variable in order to count how many individuals would be under these conditions, and to verify whether there was a correlation with the initial values of these same individuals. However, this would only be possible if the two groups (surgical-orthodontic group and orthodontic camouflage group) present homogeneous pre-treatment characteristics. For example, although the study by Proffit et al. included an unsuccessful orthodontic treatment group, the pre-treatment characteristics were not the same as those in the successful group, so the conclusions established cannot be widely accepted[14]. The study by Tulloch et al. included four subgroups of patients with class II malocclusion: a successful orthodontic treatment subgroup, a failed orthodontic treatment subgroup, a successful surgical-orthodontic treatment subgroup, and a failed surgical-orthodontic treatment subgroup[26]. However, that study included patients who were in the growth period.

Of the studies included in the qualitative synthesis, only the studies by Chaiyongsirisern et al.[5], Mihalik et al.[1] and Cassidy et al.[11] presented follow-up results. The study by Chaiyongsirisern et al. was the only one that included a similar follow-up for both treatments and that considered the changes during treatment[5]. Future studies should present the same follow-up period for both treatments.

The first year after orthognathic surgery is the period in which the major changes occur. These changes result from the entire process of post-surgical healing, completion of orthodontic treatment, and physiological adaptation of the tissues. Consequently, it is suggested that follow-up assessments be performed 1 year after the completion of treatment and after 5 years[7]. The study by Mihalik et al. even included a follow-up period of more than 10 years[1].

Studies should present better methodological quality, since only four of the studies included had a score above 16 points, and only one was included in the meta-analysis. It would have been advantageous to include all of them in the meta-analysis, but unfortunately it was these moderate quality studies that had to be excluded. The studies of Mihalik et al.[1] and Cassidy et al.[11] did not have all the necessary information to perform a meta-analysis and the study by Bollen and Hujoel[12] did not have a comparable study design. In general, these studies did not start with homogeneous treatment groups, they did not present sufficient information to verify whether the sample was representative of the entire population, and they did not conduct a power analysis or a calculation of the sample size. Future studies should be more careful about all of these factors.

Through visual inspection of the funnel plots, it seems that studies with larger sample sizes are required.

At the beginning of treatment, all patients in both groups presented a skeletal class II malocclusion due to mandibular retrognathia: ANB values above the norm, SNA within the norm, and SNB below the norm.

Prior to the start of treatment, the patients should present homogeneous characteristics[27]. However, since this meta-analysis included non-randomized clinical trials, it was relevant to confirm that pre-treatment characteristics were not influencing the overall effect.

For all sagittal skeletal measurements, the initial values were generally higher in the surgical-orthodontic group than in the orthodontic camouflage group: the pre-treatment SNB angle was slightly more severe in the orthodontic camouflage group, and the ANB and SNA angles were more severe in the surgical-orthodontic group. So, on balance, patients in the surgical-orthodontic group initially had a more severe skeletal class II malocclusion.

The ANB angle is influenced by several factors: the anteroposterior position of nasion, the vertical height of the face, and the position of alveolar points. Point B does not consider the morphology of the chin, which is the position of pogonion. Therefore, a less severe SNB value may not reflect the actual mandibular positioning[28,29].

There was no change in the overall effect size regarding the sagittal skeletal measurements after the sensitivity analyses. Thus, the treatments were considered equivalent for the SNA variable, and surgical-orthodontic treatment was considered more effective than camouflage treatment for the ANB and SNB variables. These results are in accordance with previous studies, which have demonstrated improvements in sagittal skeletal variables in patients undergoing mandibular advancement surgery[30–32].

In the vertical measurement of the ML/NSL angle, the sensitivity analysis resulted in a different overall effect size. If only patients undergoing mandibular advancement are considered, surgical-orthodontic treatment was more effective than orthodontic camouflage, although it is important to keep in mind that the initial and final values were always within the norm in both groups.

In the study by Proffit et al., the initial mean value of the ML/NSL angle was exactly the same pre- and post-treatment, possibly because the vertical increasing effect of mandibular surgery was cancelled out by the effect of the vertical reduction from maxillary impaction and bimaxillary surgery[14].

It was not possible to use the Wits variable in this meta-analysis, since only two studies evaluated this[2,5]. Wits variable would have overcome some of the limitations of the ANB angle. This variable measures the linear distance AO–BO, which is based on the projection of points A and B on the occlusal plane. Consequently, as it relates the maxilla and mandible to the occlusal plane, the rotation of the jaws will not affect the severity of the anteroposterior disharmony of the bone bases[33,34]. Future studies should include Wits measurement in their analysis.

For all studies and both treatment groups, mean overjet values were above the norm at the beginning of treatment. Therefore, most patients had a class II, division 1 status. Overbite values were also above the norm for most studies.

With regard to these dental measurements, pre-treatment values clearly differed between groups, and if these discrepancies are taken into account, the overjet and the overbite will have different final effects, depending on the severity of the initial values.

For overjet, the study by Kabbur et al.[4] could not be included in the sensitivity analysis. However, taking into account the effect size of this study, it would probably be included in the subgroup of greater than -0.5, in which, according to the overall effect, the treatments were considered equivalent.

There was a greater reduction in overjet in the surgical-orthodontic group, possibly because the correction was mostly skeletal, whereas in the camouflage group it was mostly dental. There are studies that have already distinguished the dental and skeletal overjet components for each treatment group[2,5,32].

An evaluation of the incisor mandibular plane angle (IMPA), which is the angle formed between the inclination of the lower incisor and the mandibular plane, would be pertinent and helpful. Generally, this angle is increased in orthodontic camouflage cases in order to reduce the overjet, in contrast to cases treated with surgical-orthodontic treatment where, prior to orthognathic surgery, this angle must be reduced with the purpose of reaching values within the norm[35,36]. Future studies should take this into account, as it was not possible to include the IMPA variable in the present meta-analysis due to the fact that it was evaluated in only two studies[3,4].

In the surgical-orthodontic treatment group, there was usually a slight increase in the distance between Ricketts' aesthetic line (E-line) and the lower lip, with consequent retrusion of the lower lip. However, these results should be interpreted with caution, because the E-line does not remain in the same reference position due to mandibular advancement surgery. In the study by Kinzinger et al.[3], maxillary extractions were used in group 1 as a camouflage method, which led to lower incisor retroinclination and greater lower lip retrusion. Compared to other reference lines for the lip position, the E-line appears very convenient due to its anterior location, although it has limitations in terms of consistency and sensitivity[37]. Therefore, the true vertical subnasal line may be preferable, due to its independence from the position of the chin and also because it overcomes the limitations of other reference planes[38]. Future studies should include this type of reference for sagittal aesthetic measurements.

The initial values for convexity of the skeletal profile and for the soft tissue profile were higher in the camouflage group than in the surgery group in most studies. Therefore, camouflage patients initially presented a lower convexity and, consequently, a less severe pre-treatment condition in comparison with surgical-orthodontic patients.

The overall effect sizes of the convexity variables for the skeletal profile (N–A–Pog) and soft tissue profile (N′–Sn–Pog′ and N′–Pn–Pog′) seem to be related to each other. The overall effect size indicated a greater increase in the N–A–Pog and N′–Sn–Pog′ angles, without differences between treatments. Finally, with regard to the N′–Pn–Pog′ angle, surgical-orthodontic treatment was considered more effective than orthodontic camouflage.

Surgical-orthodontic treatment showed more pronounced changes in the convexity of the skeletal profile (N–A–Pog), possibly because the pogonion point becomes more anterior with mandibular advancement surgery. An increase in this angle was also found in the camouflage group with extractions, although due to different reasons and with less alterations. In this group, there was retrusion of the upper incisors, with consequent remodelling of the position of point A.

In the quantitative synthesis, four studies used fixed appliances to camouflage class II malocclusion[2–5], and three of them evaluated the LL–E-line and profile measurements[2,3,5]. There is a possibility that the camouflage group showed improvements in these parameters due to the stimulation of condylar growth and remodelling of the glenoid fossa. Therefore, the use of these appliances in adult patients appears worth considering.

The nasolabial angle (Cm–Sn–UL) was not included in this meta-analysis. However, future studies should consider this angle. For example, in patients who undergo orthodontic camouflage with upper extractions there is usually an increase in this angle that may be detrimental to the patient's profile. In contrast, in surgical-orthodontic treatment with mandibular advancement, no great changes occur[3].

In summary, surgical-orthodontic treatment was found to be more effective for skeletal measurements (ANB, SNB) and convexity of the soft tissue profile including the nose (N′–Pn–Pog′). However, camouflage treatment may represent an alternative to surgical-orthodontic treatment, mainly in terms of the LL–E-line and profile measurements: convexity of the skeletal profile (N–A–Pog) and convexity of the soft tissue profile excluding the nose (N′–Sn–Pog′). It is important to emphasize that for the majority of the measurements, especially the dental ones, patients undergoing surgical-orthodontic treatment presented a more severe pre-treatment condition. These conclusions should be interpreted with caution, due to the limited number of studies included and because they were non-randomized clinical trials. Further studies with larger sample sizes, similar pre-treatment conditions, and appropriate periods of follow-up are needed.

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Patient consent

Not required.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijom.2017.09.003.

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