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Prevalence of maxillary sinus septa: systematic review and meta-analysis

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Abstract. The aim of this systematic review and meta-analysis was to determine the prevalence and characteristics of maxillary sinus septa using cone beam computed tomography and computed tomography data. Publications were searched until October 5, 2020 in three electronic databases. Additionally, article bibliographies were searched, and authors were contacted if required. This review has been registered in PROSPERO (CRD42019124933). Two independent evaluators assessed methodological quality using the Joanna Briggs Institute levels of evidence; inter-rater reliability tests were performed (Cohen's κ). The prevalence of maxillary sinus septa was expressed as a proportion; differences according to sex were reported in terms of the odds ratio (OR) and 95% confidence interval (95% CI). Heterogeneity and sources of heterogeneity were evaluated by meta-regression. Publication bias was assessed by visual analysis of the funnel plot. Statistical significance was set at $P < 0.05$. The 62 studies identified and included in the review involved 13,701 patients (22,460 sinuses). The meta-analysis of 35 studies (14,664 sinuses) revealed an overall mean sinus septa prevalence per sinus of 33.2% (95% CI 27.8–38.5%; $I^2 = 98.32\%$). The meta-analysis of 42 studies (9631 patients) found an overall mean sinus septa prevalence per patient of 41.0% (95% CI 36.0–46.0%, $I^2 = 96.45\%$). The OR for the difference in septa prevalence between sexes was 0.785 (95% CI 0.590–1.046; $P = 0.098$, $I^2 = 73.24\%$). Septa were most frequent in the middle area of the sinus and with a transverse orientation (86.0%). Within the limitations, the results suggest a high proportion of septa in the sinus, commonly in the middle area, which can interfere with the success of sinus floor elevation required for implant rehabilitation.

Key words: tomography; cone-beam computed tomography; prevalence; maxillary sinus; sinus floor augmentation.

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Implant placement in the posterior maxilla may be a challenging surgical procedure in the presence of a reduced vertical bone height. Tooth loss leads to increased osteoclastic activity and bone resorption, causing an inferior expansion of the sinus. Consequently, the edentulous posterior maxillary alveolus results in low-density trabecular bone, sometimes with insufficient vertical bone height for rehabilitation with implants[1]. The sinus floor elevation (SFE), or sinus lift procedure,

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can be performed in such cases of bone deficiency to allow dental implant placement[2,3].

SFE has become standard care in implant dentistry, with excellent long-term (≥5 years) implant survival/success rates[4–6]. Although SFE is considered a relatively safe surgical procedure, complications may arise from inadequate planning or aggressive surgical manoeuvres[7]. Perforation or damage to the Schneiderian membrane is the most common intraoperative complication during SFE, with an estimated prevalence of between 11% and 56%[8–11], which might lead to graft migration and sinus infection[12]. Thus, an intact Schneiderian membrane is desirable to ensure the success of the bone graft and subsequent implant rehabilitation[13].

The presence of maxillary sinus septa (MSS) has been associated with an increased risk of sinus membrane perforation[2,3,14]. It is one of the most common anatomical variations occurring in maxillary sinuses, with an estimated prevalence of between 28% and 58%[15,16], along with sinus pneumatization[16]; both of these variations can condition the outcome of the surgical procedure.

Knowledge of the locations and morphology of septa is essential to determine the surgical approach for SFE[14,17,18], since medium-size septa need to be resected for the assessment of the palatal area of the sinus cavity, and high septa lead to partial or complete separation of the sinus cavity, requiring the preparation of two or even three cavities during the SFE procedure[19].

The aim of this review was to answer the following CoCoPop (Condition, Context, and Population) framework question[20]: What is the prevalence of MSS in patients undergoing cone beam computed tomography or computed tomography?

This review is categorized as level 4a: systematic review of descriptive studies.

Methods

Protocol and registration

This systematic review has been registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42019124933) and was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[21].

Eligibility criteria

Articles were included in this systematic review if they clearly met the following inclusion criterion: randomized clinical trials, controlled clinical trials, prospective cohort studies, or retrospective studies; results evaluated by three-dimensional (3D) imaging (cone beam computed tomography (CBCT) or computed tomography (CT)); in vivo human studies; sample size given (per sinus and/or per patient) or calculable; population aged ≥16 years. No date limits or language restrictions were applied.

Narrative review studies, case reports, studies in which the sample had been partially analysed in other included studies, and articles without an abstract or full text were excluded.

Literature search strategy

Three electronic databases were accessed and searched up until January 2019 (PubMed, LILACS, and the Cochrane Library). The search was undertaken using the following combination of terms: ''Tomography''[MeSH Terms] OR ''Cone-Beam Computed Tomography''[MeSH Terms] AND ''Prevalence''[MeSH Terms] AND maxillary sinus septa prevalence; ''Tomography''[MeSH Terms] OR ''Cone-Beam Computed Tomography''[MeSH Terms] AND ''Prevalence''[MeSH Terms] AND maxillary sinus septa; ''Tomography''[MeSH Terms] OR ''Cone-Beam Computed Tomography''[MeSH Terms] AND maxillary sinus septa prevalence; ''Tomography''[MeSH Terms] OR ''Cone-Beam Computed Tomography''[MeSH Terms] AND maxillary sinus septa; ''Prevalence''[MeSH Terms] AND maxillary sinus septa; ''Maxillary sinus septa prevalence''; ''Maxillary sinus septa''; ''Tomography AND maxillary sinus septa prevalence''; ''Cone-Beam Computed Tomography AND maxillary sinus septa''.

The bibliographic references of the selected studies were assessed manually. All of these searches were repeated on a further date (October 5, 2020), and 12 new articles were included in the review[22–33].

The corresponding authors of the potentially relevant articles or articles for which the data needed further clarification were contacted via e-mail and they were questioned regarding additional research work on the subject and whether they were aware of any ongoing project that could also be included.

Data extraction

The study selection followed a three-stage assessment. In the first stage, all titles and abstracts were screened for the eligibility criteria by two independent reviewers. In the second stage, the full texts of relevant papers were analysed, and the same eligibility criteria were applied. In the third stage, the selected articles were submitted to a critical appraisal in terms of their scientific merit.

The data collected from the articles included in the final selection consisted of (1) study characteristics: author, year of publication, country, and study design (prospective or retrospective); (2) demographic data: sample size, mean age (years), and sex (male/female); and (3) outcome measures: assessment of the presence and characteristics of MSS.

Assessment of scientific merit

Systematic reviews rely on the use of tailored critical appraisal checklists to assess the quality of particular study designs. In this review, the Joanna Briggs Institute (JBI) critical appraisal tool for prevalence studies was used[20]. Two evaluators (I.H., D.M.) independently assessed the eligible studies and answered each JBI question with 'yes', 'no', 'unclear', or 'not applicable'. Discrepancies in the assessment were discussed until a consensus was reached. Inter-rater reliability tests were undertaken for both evaluators using Cohen's kappa (κ) coefficient ± asymptotic standard error (ASE) for overall score[34]. The final score for each study assessed with the JBI questions was calculated based on the percentage of positive answers ('yes'). The risk of bias (RoB) was categorized according to the final score as 'high' (≤49%, leading to article exclusion), 'moderate' (50–69%), or 'low' (≥70%)[35]. None of the studies was excluded following the overall appraisal.

Statistical analysis

The prevalence of MSS was calculated based on the prevalence reported in the included studies with a random-effects model, using OpenMeta[Analyst] software (v. 10.12; http://www.cebm.brown.edu/openmeta/). The results were presented as forest plots displaying the odds ratio (OR) and untransformed proportions, with the 95% confidence interval (CI). The Cochran Q test and the I^2 statistic were used to measure the proportion of statistical heterogeneity in the proposed outcomes, quantified as low (25%), moderate (50%), and high (75%). Heterogeneity was considered significant at $I^2 \geq 50\%$[36]. Meta-regression was conducted to identify possible sources of between-study heterogeneity in the pooled proportion estimates using the type of imaging examination (CT/CBCT) as a categorical variable[36]. Omnibus tests were performed to assess the explainable variance for each evaluated outcome. A visual analysis of the funnel plot was undertaken to assess publication bias for the evaluation of sex, using RevMan software (RevMan v5.3.5; Cochrane Collaboration, Denmark). Statistical significance was set at $P < 0.05$.

Results

The electronic search resulted in 112 articles after the removal of duplicates. Two papers were added after analysing the bibliographic references of the included articles, and another after contact with the corresponding authors of the selected studies via e-mail (21% response rate). Twelve additional papers[22–33] were included after repeating the search on a more recent date (October 5, 2020). Following methods described previously, these articles were reduced to 62 papers, as presented in the PRISMA flow diagram (Fig. 1).

Regarding Cohen's κ for inter-rater reliability, this was an average 0.75 ± 0.06, indicating substantial agreement between the two reviewers. The studies presented an overall average JBI score of 62.9% (95% CI 49.5–67.9%). Visual analysis of the funnel plot for sex bias detected asymmetry, which could be due to publication bias or small study effects (Fig. 2).

Synthesis of results

Supplementary Material Table S1 summarizes the information collected from the selected studies[11,17,22–33,37–84]. In total, 62 articles were included, evaluating a total of 22,460 sinuses and 13,701 patients. These articles described the prevalence of MSS either per sinus (I) or per patient (II). Studies that reported the prevalence of septa per sinus (I) (n = 35) included 14,664 sinuses in 8080 patients, and studies that reported the prevalence of septa per patient (II) (n = 42) included 16,014 sinuses in 9631 patients.

Septa proportion (per sinus and per patient)

The proportion of MSS detected was 33.2% (95% CI 27.8–38.5%; I^2 = 98.32%) per sinus (I) and 41.0% (95% CI 36.0–46.0%, I^2 = 96.45%) per patient (II) (Figs 3 and 4). The detected differences in septa prevalence between the sexes equated to an OR of 0.785 (95% CI 0.590–1.046, P = 0.098, I^2 = 73.24%).

When evaluating the presence of bilateral septa, 13 articles provided this information[23,25,30,39,45,47,58,62,67,69,70,80,84], and 13.3% of the corresponding pooled population (542 of 4067 patients) had bilateral septa.

Number of septa (per sinus and per patient)

Twelve studies (2630 patients, 5104 sinuses) reported information on the number of septa per sinus[30,33,40,41,47,53,55,65,66,68,70,82], with 21.2% of the sinuses presenting one septum (1080 of the total 5104 sinuses) and 2.8% presenting more than one septum (two septa in 2.4%, three septa in 0.3%, four septa in 0.02%).

Fourteen studies (3594 patients, 6553 sinuses) reported information on the number of septa per patient[22,23,25,39,44,52,53,56,58–60,72,73,75], with 29.4% of the studied patients having one septum (1056 of the total 3594 patients) and 20.9% of the total patients having more than one septum (two septa in 14.5%, three septa in 4.8%, four septa in 1.4%).

Location and orientation of septa

Eighteen studies divided the sinus according to the classifications of Velásquez-Plata et al. and Kim et al.[22,25,30,33,40–42,46,52,53,56,58,59,65,70,72,73,75], one study described four areas that could be accounted together with the Velásquez-Plata classification[23], two studies divided the septa according to the Underwood classification[39,49], one study used the classification proposed by Krennmair et al.[60,83], and one study used a different description[47]. The studies that used the classification of Velásquez-Plata et al. and Kim et al. corresponded to 5154 patients and 9745 sinuses, and reported 3392 septa, with half of the septa found in the middle area (49.4%, n = 1674), followed by the posterior (25.2%, n = 854) and the anterior (20.7% n = 701) zones. The studies that followed the Underwood classification found 42.0% of the septa in the middle region (n = 145), 39.7% in the anterior region (n = 137), and 18.3% in the posterior region (n = 63).

Ten articles described septa orientation, accounting for 3983 sinuses and a total of 1489 MSS[17,22,25,33,39,53,58,60,68,72]. The most frequent orientation was the coronal/transverse (86.0% of the sinus septa), followed by the sagittal/vertical (10.1%) and axial/horizontal (3.9%).

Study characteristics

The included studies were published between 1997 and 2020, and the samples were from 17 different countries, with populations in Turkey[22,27,31,37–43], Brazil[44–48], Iran[28,49–52], and Switzerland[11,53–55] being the most frequently assessed.

Regarding the sex of the included populations, 55 articles reported 5981 female patients (52.2%) and 5467 male patients (47.8%). However, regarding comparison between the sexes, only 17 studies presented the results of MSS prevalence by sex[24,25,33,39,40,42,47,48,51–53,55–60], with 55.1% (1875/3404) of participants being female. A visual analysis of the funnel plot was undertaken to assess publication bias for the sex evaluation, and asymmetry was detected (Fig. 2). The included patients ranged in age from 16 to 92 years, based on the 44 studies that reported this information (10,443 patients, 17,855 sinuses)[11,22,23,25,27–32,38–41,43,45,47–58,60–75].

The prevalence of MSS was analysed by CBCT in 39 studies (9325 patients, 14,335 sinuses)[11,22,24,25–27,29–33,38,40,41,44–47,49–51,53–56,61,64,67–69,71–73,76–81] and by CT in 23 studies (4376 patients, 8125 sinuses)[17,23,28,37,39,42,43,48,52,57–60,62,63,65,66,70,74,75,82–84]. A meta-regression was performed to assess the type of imaging examination (CBCT vs CT) as a heterogeneity factor for the pooled proportion of sinus septa per sinus (I) and per patient (II). A statistically significant P-value ($P < 0.001$) was obtained for sinus septa per sinus, thus confirming the type of examination as a possible heterogeneity factor, with higher results found in studies that used CBCT (40.9%, 95% CI 34.6–47.2%) when compared to CT (23.5%, 95% CI 16.4–30.6%). On the other hand, when the prevalence per patient (II) was evaluated, a non-significant P-value was found (P = 0.789).

Discussion

The aim of this systematic review was to evaluate the available scientific evidence on MSS prevalence in patients submitted to 3D examinations. Qualitative analyses for subgroups including sex, number of septa, and location of septa were also performed. The proportion of MSS found was 33.2% per sinus (95% CI 27.8–38.5%, n = 14,664) and 41.0% per patient (95% CI 36.0–46.0%, n = 9631).

This systematic review is novel in presenting the results based on both CBCT and CT imaging examinations, regarding the prevalence of septa per sinus and per patient.

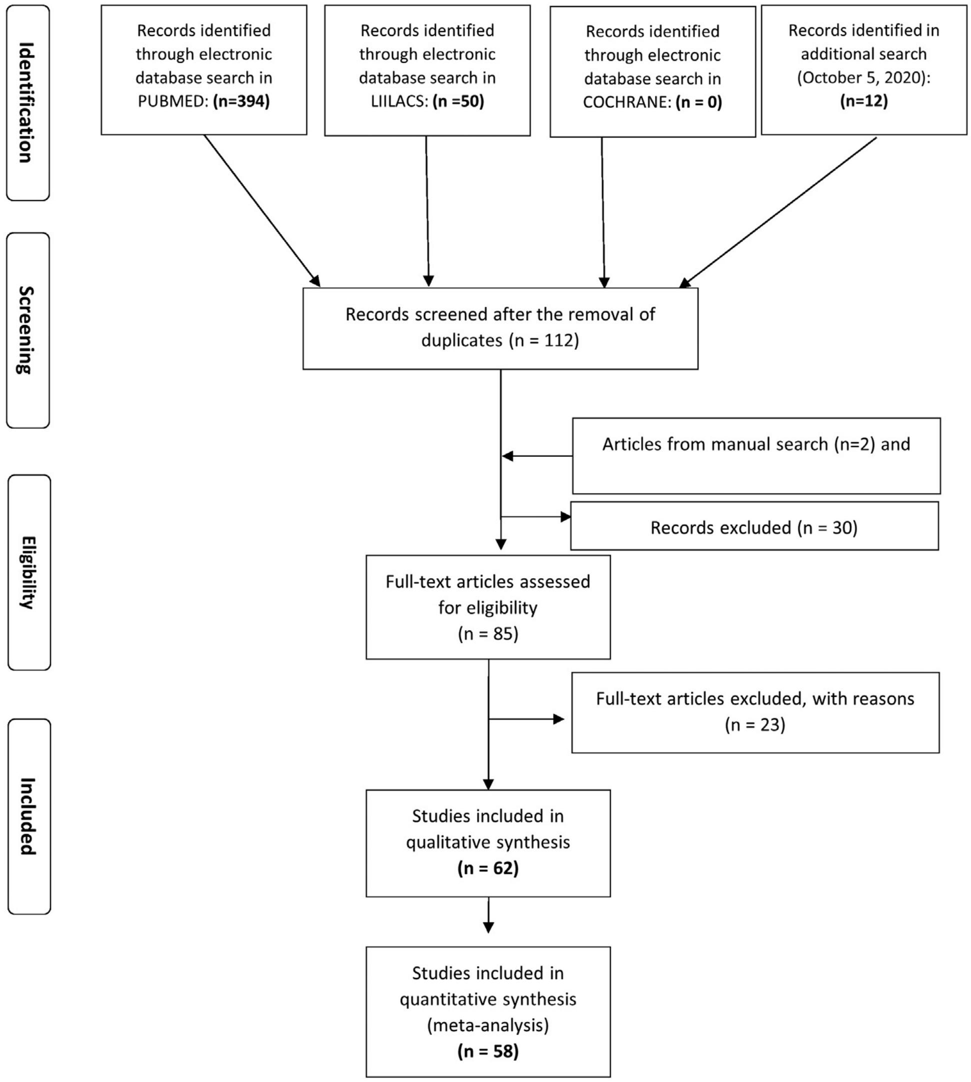

Fig. 1. Flow diagram of the search strategy.

When taking into consideration the previous systematic reviews, in 2010 Maestre-Ferrín et al.[85] reported a prevalence of septa ranging between 13% and 35.3%, although the included studies presented heterogeneous designs: dry skulls, observation during surgery, 2D examinations (panoramic X-ray), and 3D examinations (CT) were included. In 2012, Pommer et al.[15] performed a systematic review on the prevalence of sinus septa per se that included studies with 3D CT images and data from visual inspection during surgery (n = 729) and cadavers (n = 426), which reported a prevalence of 28.4%. The most recent systematic review by Ata-Ali et al.[16] published in 2017 reported the anatomical variations in the maxillary sinus and included studies published up until 2015 that used CBCT images; five of the studies reported information regarding the prevalence of MSS, which ranged from 7.5% to 66% (n = 2437).

In the present study, a meta-regression was performed to evaluate the possible influence of the minimum age included in each study, but no significant difference was obtained (a P-value of 0.332 for the prevalence of septa in the sinus). Thus, an age limit of 16 years was considered since, according to the literature, the maxillary sinus presents an adult configuration at that age[86,87].

When evaluating the available data for septa location, about half of all MSS were located in the first and second molar areas, corresponding to the segment where most of the sinus space resides[1]. This finding is of the utmost importance for implant surgery procedures, since the first and second molar locations are some of the most affected areas regarding residual bone height after tooth extraction, usually with the need to perform SFE procedures[1].

Septa orientation is considered a potential factor in SFE surgery outcomes, since this could lead to incomplete elevation of the Schneiderian membrane or even rupture[2,3,14]. Ten articles evaluated septa orientation, and 86.0% of the detected septa divided the sinus into two sections with a coronal/transverse/buccopalatal orientation[22,25,33,39,53,58,60,68,72,83]. According to Irinakis et al.[77], this orientation presents a higher risk of membrane perforation, with the severity depending on the size and

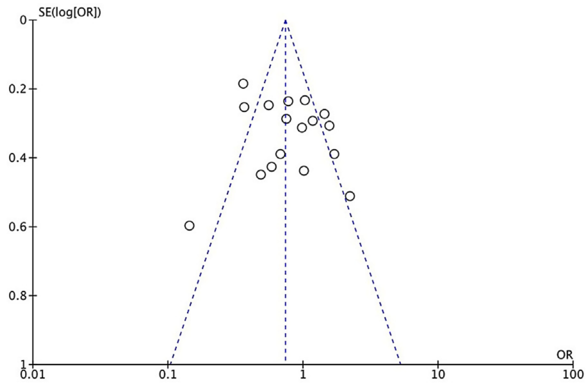

Fig. 2. Funnel plot for publication bias according to patient sex.

height of the septa. Fourteen percent of the evaluated septa presented a sagittal or axial orientation. These orientations can present a higher risk of not being detected if only panoramic X-rays are performed prior to SFE surgery. Moreover, axially orientated septa can be confounded with the mesial wall of the sinus, with subsequent non-augmentation of the medial portion of the sinus cavity. Taking the results obtained into consideration, a mandatory CBCT/CT should be considered prior to sinus lift surgery[4,15].

In this study, the JBI checklist for prevalence studies was used, resulting in a JBI score of 62.9%, which corresponds to a moderate RoB. Some of the most poorly addressed aspects in the studies analysed were the appropriate recruitment of the study population, the use of an adequate sample size, and the validation of intra-observer and/or inter-observer reliability in the evaluation of 3D examinations, factors that could influence the heterogeneity between studies. According to the JBI levels of evidence, a systematic review of prevalence studies is categorized as level 4a, corresponding to a low level of evidence, with some degree of heterogeneity among the included studies. Thus, these results should be interpreted with caution regarding external validity.

According to the results of this review, at least one-third of patients present maxillary septa, most frequently in the middle area of the sinus, which can interfere with the success of sinus floor elevation required for implant rehabilitation. Mandatory 3D images should be performed prior to sinus lift surgery in order to increase the predictability of treatment.

Funding

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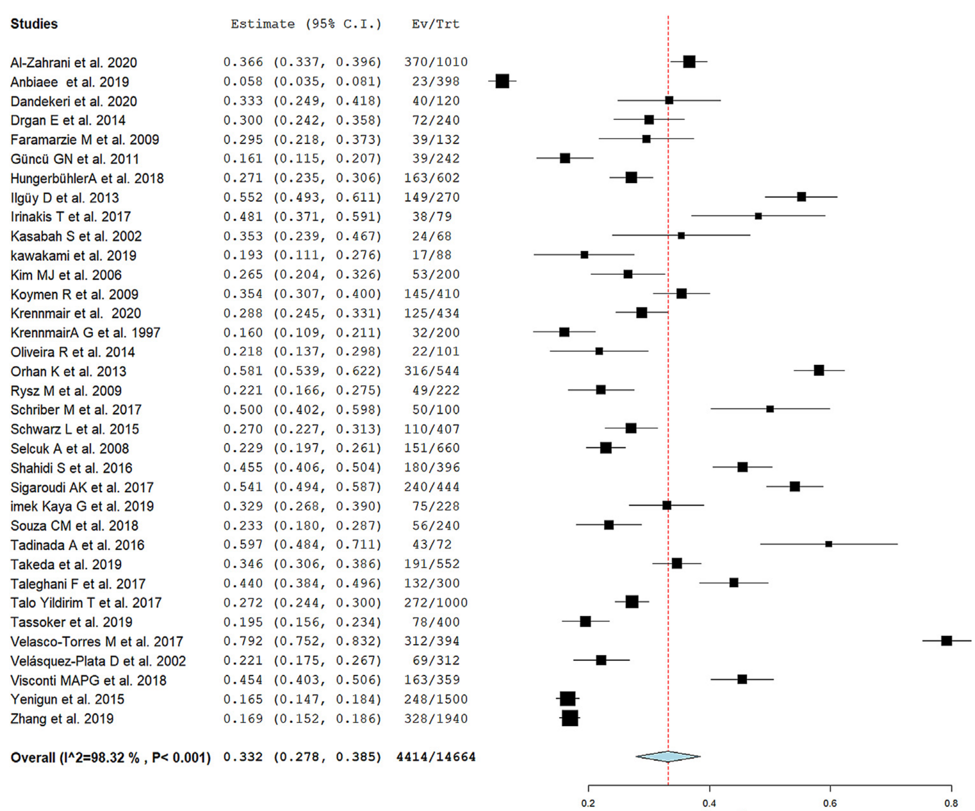

Fig. 3. Forest plot of the proportion of maxillary sinus septa per sinus. Ev represents the number of septa and Trt the number of sinuses. The red line represents the average of all of the results. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

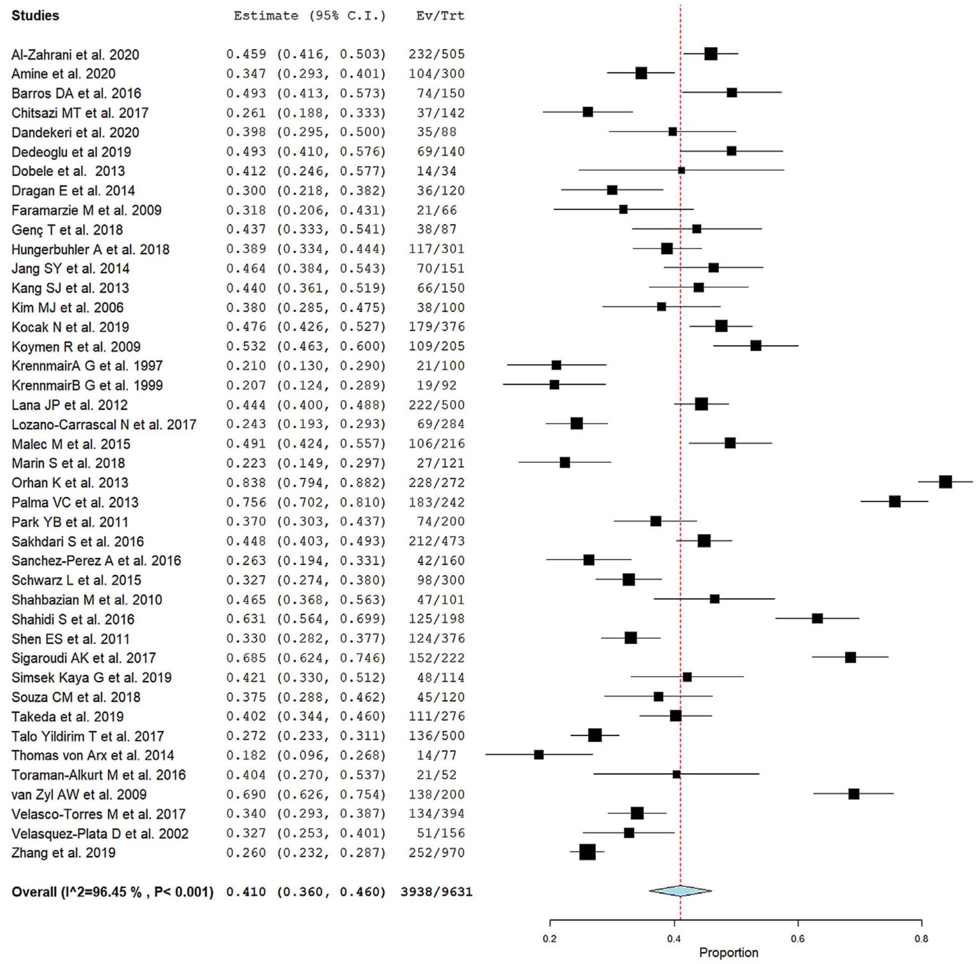

Fig. 4. Forest plot of the proportion of maxillary sinus septa per patient. Ev represents the number of septa and Trt the number of patients. The red line represents the average of all of the results. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Competing interests

None.

Ethical approval

Not applicable.

Patient consent

Not applicable.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijom.2021.10.008.

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