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Systematic Review

The Evaluation of Maxillary Sinus Dimensions in Different Craniofacial Patterns: A Systematic Review and Meta-Analysis

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Main Points

- Maxillary sinus dimensions differ in different craniofacial patterns.
- The maxillary sinus dimensions are greater in Class II skeletal malocclusion and in hyper-divergent male individuals.
- Knowledge about sinus dimensions is critical in orthodontics during placement of mini-implants, mesialisation of molars, and intrusion of posterior teeth.

ABSTRACT

This systematic review was intended to evaluate the maxillary sinus dimensions in vertical and sagittal craniofacial patterns and to assess if there was a difference among the craniofacial patterns. A systematic search was performed in seven databases till February 2021. The risk of bias was performed with modified Newcastle Ottawa scale. Meta-analysis was performed using random effects model. Twelve studies were included in the review and 8 in the meta-analysis. Compared to Class I malocclusion, the maxillary sinus area is greater in Class II and lesser in Class III malocclusion. On comparing normo-divergent growth pattern, the maxillary sinus area is lesser in hypo-divergent and greater in hyper-divergent individuals. Most of the studies were graded as satisfactory. The measurements are greater in hyper-divergent Class II malocclusion and in males.

Keywords: Maxillary sinus, growth patterns, malocclusion, systematic review

INTRODUCTION

Maxillary sinus is an air-filled, pyramidal-shaped structure present in the body of the maxilla.[1] The size and shape of the maxillary sinus determine the facial appearance.[2] Proffit et al.[3] showed that long-face adults had 2 to 3 times smaller occlusal forces than those with a normal face. The lighter bite force in hyper-divergent and large gonial angle patients results in an increase in sinus volume.[4] However, Oksayan et al[5] and Yassaei et al.[6] have shown that maxillary sinus dimensions are reduced in hyper-divergent individuals and vice versa. Goymen et al.[7] and Bassil-Nassif et al.[8] found no difference in the sinus dimensions among individuals with various mandibular growth patterns. The literature available regarding the relationship of the size of the maxillary sinus and sagittal malocclusion is conflicting.[9-11]

The size of the maxillary sinus is important in the field of dentistry during placement of implants, mini-screws, augmentation procedures, mesialisation of second molars in place of first molars, and intrusion of maxillary molars.[4]

As there are controversies in the literature on the relationship of the maxillary sinus dimensions in different growth patterns and with skeletal sagittal malocclusion, a systematic review is warranted.

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Therefore, the aim is to evaluate the maxillary sinus dimensions in vertical and sagittal craniofacial patterns and to assess if there is a difference in the maxillary sinus dimensions among these craniofacial patterns.

METHODS

The review question was "Is there a difference in the maxillary sinus dimensions in the craniofacial patterns?"

Eligibility Criteria:

The inclusion and exclusion criteria were:

Inclusion Criteria:

Population: General population.

Intervention: Maxillary sinus dimensions using 2D and #D radiographs.

Comparison: Maxillary sinus dimensions in individuals with different sagittal malocclusions and mandibular growth patterns.

Outcome: Maxillary sinus dimensions.

Type of studies: All studies.

Exclusion Criteria

Any existing pathological condition in the sinus such as tumours or cysts, previous orthodontic treatment, facial asymmetry, craniofacial syndromes, cleft lip and palate.

All types of studies were included.

Information sources, search strategy, and study selection

Electronic searches were conducted until February 28th 2021, across 7 databases: PubMed, OVID, Cochrane library, LILACS, Scopus, Web of Sciences, and Embase. The search strategy included the use of MeSH (Medical Subject Headings), keywords, Boolean operators "AND" and "OR", for each database. The key words for PUBMED were "maxillary sinus", "malocclusion" and its variants, "normo-divergent", hypo-divergent and hyper-divergent and its variants. They were suitably modified for other databases.

The Initial screening of articles identified in the databases searched involved independent screening of title and abstract by 2 reviewers (R.C and P.R) on the basis of the research question and against the inclusion and exclusion criteria. In articles where the title and abstract failed to provide sufficient information, the full text was reviewed, to assess for relevance. They were then retrieved from these potentially eligible studies. To ensure that no relevant studies were missed, the reference list of the remaining articles was hand-searched. The duplicates from various databases were removed using the Mendeley software. Any discrepancies with regards to the eligibility of an article were resolved by discussion with a third reviewer (V.K.) when necessary.

Data Extraction

The data extraction of the included articles was performed independently and in duplicate by two authors. A pre-determined and standardized table was used for data extraction and study characteristics were tabulated. An attempt to contact the authors was made for any missing information.

Outcome

The outcome for which the data would be sought is the maxillary sinus height, length, width, area, and volume.

Risk of bias and quality assessment of the studies:

The risk of bias for individual studies was evaluated using the "Modified Newcastle Ottawa scale" adapted for cross-sectional studies.[12] Any disagreements over the risk of bias were resolved by discussion, with the involvement of a third reviewer.

Data synthesis: For each article that met the validity criteria, data were extracted and compiled into a table of evidence. The studies that evaluated the sinus dimensions in sagittal malocclusion and the growth patterns were grouped individually. Those studies that evaluated the sinus dimensions in both sagittal and vertical craniofacial patterns were placed in both groups. Analysis was prepared according to the Cochrane Handbook for Systematic Reviews.[13] Data for meta-analysis were analyzed in Review Manager (RevMan) 5.3.[14] An inverse variance method of pooling the data with a random-effects model was used for the meta-analysis. Heterogeneity was assessed with I^2 statistics.

Certainty of Evidence

The certainty of evidence was assessed by two reviewers using Grading of Recommendations, Assessment, Development and Evaluation (GRADE) Approach.[15]

RESULTS

The search selection process is depicted in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) 2020 flowchart (Figure 1). The search of the seven electronic databases reported 2868 records. In addition, 1 article was selected through citation search. After the removal of duplicates, 2644 articles were eliminated after reading the titles and abstracts. Of the 19 full-text documents, 7 studies were excluded. The reasons for exclusion are presented in Figure 1. Twelve studies were included in the systematic review and 8 in the meta-analysis.

Study Characteristics

The study characteristics of the studies included are given in Table 1. Among the 12 studies, 9 evaluated the maxillary sinus dimensions in sagittal malocclusion (Class I, Class II, and Class III).[6,9-11,16-20] Five studies assessed the maxillary sinus dimensions in different growth patterns.[5-7,16,21]

Risk of Bias in Studies

The quality assessment for the included studies was done using the Modified Newcastle Ottawa scale, adopted for cross-sectional studies (Table 2). Eleven studies were graded satisfactory, and

1 was graded unsatisfactory.[9] Most of the studies were graded satisfactory only, due to the lack of control of the confounding factors, and lack of standardization of the growth pattern when the sagittal malocclusion was compared and vice versa.

Maxillary Sinus Dimensions

Among the 9 studies, 4 studies concluded that there was no significant difference in the maxillary sinus dimensions in the sagittal plane (Table 3). Meta-analysis was possible for 5 studies.[6,9,10,17,19] (Figures 2-4). Among the five studies, four studies found no significant difference in the sinus area or volume among the vertical growth patterns.[5,7,16,21] Table 4 provides the details of the studies. Among the vertical patterns, the maxillary sinus height alone was smaller in hypo-divergent individuals. Other dimensions such as the length and the width were not statistically significant. The sinus area is greatest in the hyper-divergent individuals. However, the sinus volume showed no significant difference (Figures 5 and 6). Among the 13 studies, five studies revealed that males had greater sinus dimensions than females.[6,11,16,17,21] The GRADE approach indicated "low" overall certainty of evidence.

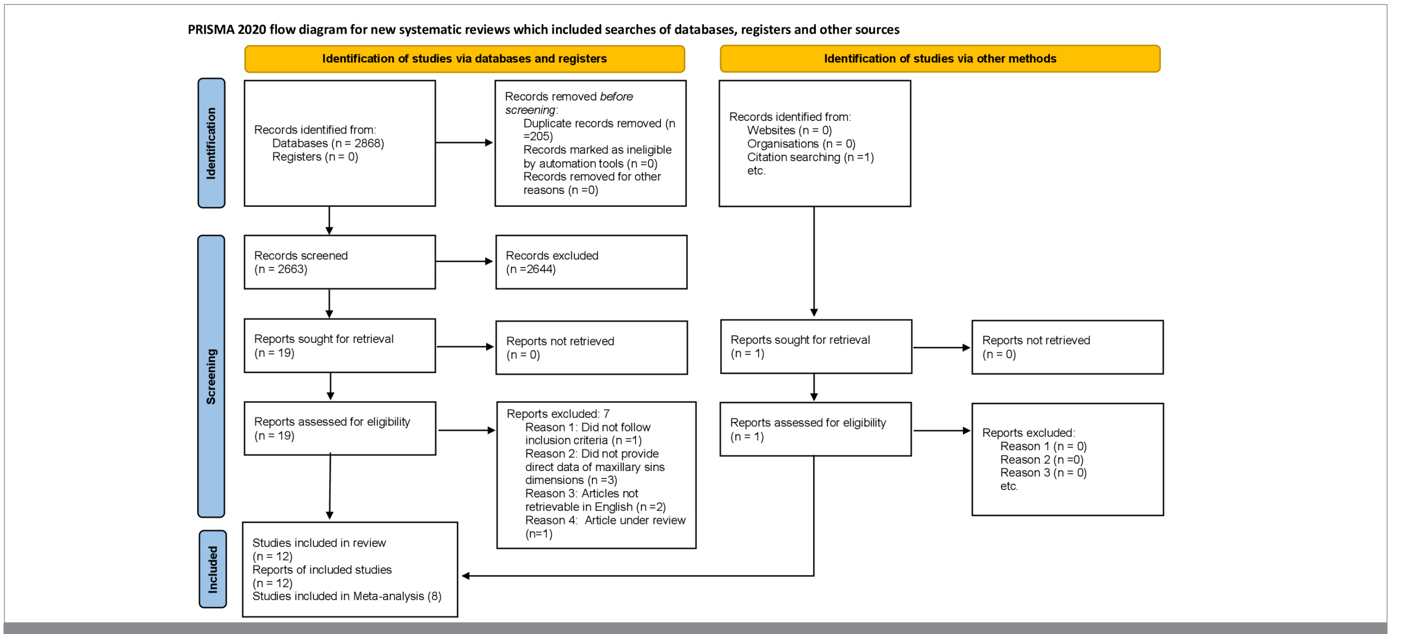

Figure 1. Search results flow diagram

Table 1. Characteristics of the included studies

Author	Study design	Age	Sample size	Radiograph	Malocclusion	Parameter
Oktay[9] 1992	Cross-sectional	6-30	189	OPG	Sagittal (Class I, Class II and Class III)	(MSA)
Endo et al .[10] 2010	Retrospective	12-16	120	LC	Sagittal	MSL, MSH, UMSA, LMSA, TMSA
Al-Ani et al.[21] 2011	Retrospective	18-25	60	LC	Vertical (Normo, Hypo and Hyper-divergent)	MSL, MSA, TMSA
Urabi and Al-Nakib[11] 2012	Cross-sectional	18-25	120	LC	Sagittal	MSL, MSH, UMSH, LMSA, TMSA
Dhiman et al.[19] 2015	Cross-sectional	16-25	240	LC	Sagittal	TMSA
Qadir and Mushtaq[17] 2017	Cross-sectional	15-35	90	LC	Sagittal	MSL, MSH, UMSA, LMSA, TMSA
Oksayan et al.[5] 2017	Retrospective	29.9±10.9	60	CBCT	Vertical	MSV, MSL, MSH, MSW
Andiappan[20] 2020	Retrospective	16-25	96	LC	Sagittal	MSA
Paluch et al.[18] 2018	Retrospective	4.4-19.3	122	LC and PA	Sagittal	MSLL; SMRPA, and SMLPA
Yassaei et al.[6] 2018	Descriptive	15-20	111	LC	Sagittal and Vertical	MSH, MSL, MSA
Goymen et al.[7], 2019	Retrospective	18-27	60	LC and PA	Vertical	MSA, MSH, MSW
Shrestha et al.[16] 2021	Cross-sectional	21-64 years	100	CBCT	Sagittal and Vertical	MSV

MSH, maxillary sinus height; MSL, maxillary sinus length; MSA, maxillary sinus area; MSW, maxillary sinus width; MSV, maxillary sinus volume; TMSA, total maxillary sinus area; UMSA, upper maxillary sinus area; LMSA, lower maxillary sinus area; LC, lateral cephalogram; OPG, orthopantomogram

Table 2. Risk of bias using MNCOS tool

Author	Selection				Comparability	Outcome		
	Representative	Sample	Ascertainment	Non-respondent	Study design or analysis	Assessment	Statistical test	Total risk of bias
Oktay[9] 1992	C	B	A*	NA	B	B**	A*	4- Unsatisfactory
Endo et al.[10] 2010	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Al-Ani et al.[21] 2011	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Urabi and Al-Nakib[11] 2012	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Dhiman et al.[19] 2015	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Oksayan et al.[5] 2017	A*	B	A*	NA	B	A**	A*	5- Satisfactory
Qadir and Mushtaq[17] 2017	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Yassaei et al.[6] 2018	B*	A*	A*	NA	B	A**	A*	6- Satisfactory
Andiappan[20] 2019	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Goymen et al.[7] 2019	A*	A*	A*	NA	B	A**	A*	6- Satisfactory
Paluch et al.[18] 2020	B*	B	A*	NA	B	B**	A*	5- Satisfactory
Shrestha et al.[16] 2021	A*	A*	A*	NA	B	B**	A*	6- Satisfactory

Table 3. Maxillary sinus dimensions in sagittal malocclusion

Author	Parameter				Outcome
		Class I	Class II	Class II	
Oktay[9]	MSA	95.39±2.9	102.2±3.5	97.4±4.3	No significant effect
Endo et al.[10]	MSA	1500.1±236.3	1501.6±239.7	1509.2±201.5	No significant effect
	MSH	45.5±5.1	45.4±5.2	46.05±4.2	
	MSL	44.9±2.5	45.5±2.7	44.9±2.7	
Urabi and Al-Nakib[11]	MSA	1361.8	1406.9	1315.5	No significant effect
	MSH	43.3	42.7	42.8	
	MSL	43.3	44.4	43.7	
Qadir and Mushtaq[17]	MSA	1702.5±224.8	1721.8±227.3	1698.4±193.2	Length is greater in Class II
	MSH	41±4.6	40.9±4.8	41.5±3.2	
	MSL	41.5±2.6	42±2.4	40.9±2.4	
Yassaei et al.[6]	MSA	836.4±139.3	812.9±125.8	928.0±134	Height and area are greater in Class III
	MSH	40.8±3.7	38.6±4.1	41.3±4.3	
	MSL	35±3.7	35.5±4.1	36±3.5	
Andiappan[20]	MSA	1728	1286.8	1244.6	Increased in Class I
Dhiman et al.[19]	MSA	1337.5±100.1	1679.7±93.2	1183.9±117	Area greater in Class II
Shreshta et al.[16]	MSV	19,889.7±6844	28,680.3±6827.6	18091±9060.5	Greatest in Class II
Paluch et al.[18]	MSA	Class I - Class II = -4.5, Class I - Class III = -140.8, Class II - Class III = -136.3			Area in Class III greater

MSH, maxillary sinus height; MSL, maxillary sinus length; MSA, maxillary sinus area; MSW, maxillary sinus width; MSV, maxillary sinus volume

DISCUSSION

This systematic review was done to assess the maxillary sinus dimensions in various craniofacial patterns and to assess if the different craniofacial patterns have an influence on the sinus dimensions.

The proximity of the sinus floor with the root apex has its importance in the field of orthodontics.[4] Apart from the orthodontic side effects such as root resorption and pulp vitality,[22] the movement of the tooth against the cortical bone is another challenging problem to address.[23] Hence, the evaluation of the maxillary sinus dimensions among various craniofacial patterns is relevant for orthodontic treatment.

Among the 12 studies, Oktay[8] was graded as unsatisfactory because of the lack of skeletal classification of malocclusion and lack of availability of the statistical information. Only Shreshta et al.[16] and Goymen et al.[7] provided the justification for the sample

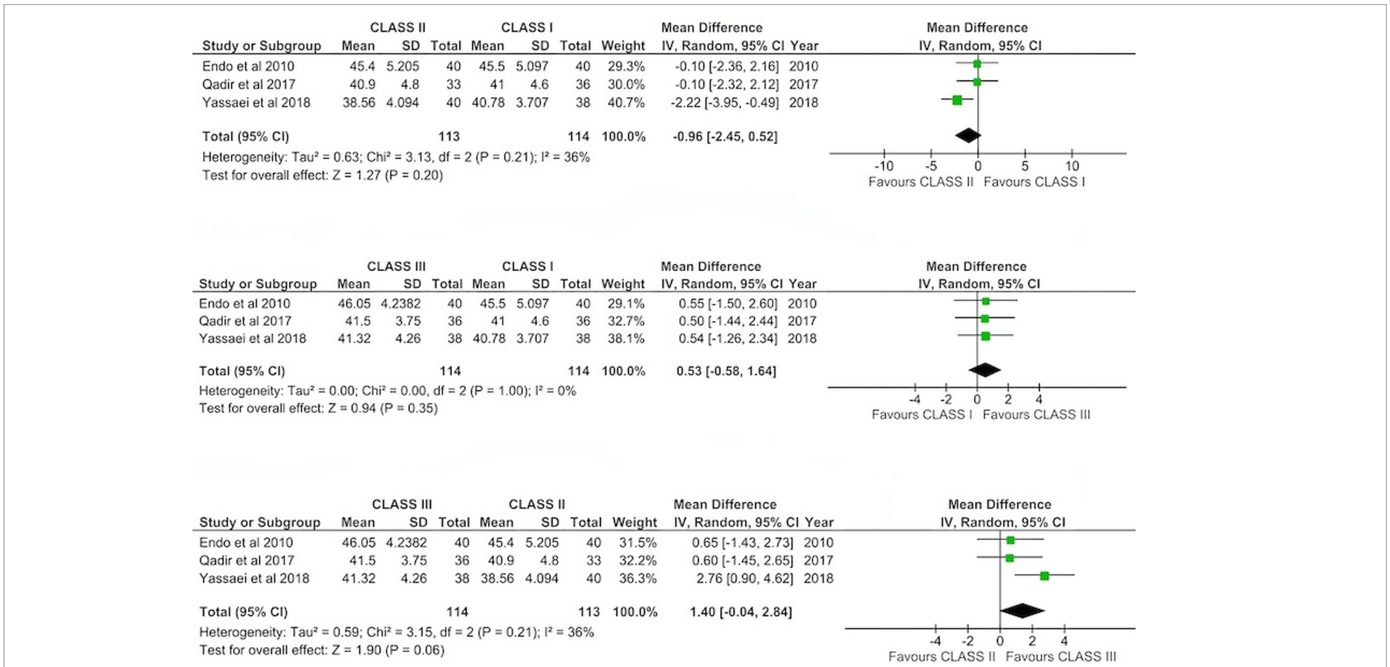

Figure 2. Forest plot comparing the maxillary sinus height between Class I, Class II and III sagittal malocclusion.
df, degrees of freedom; CI, confidence interval

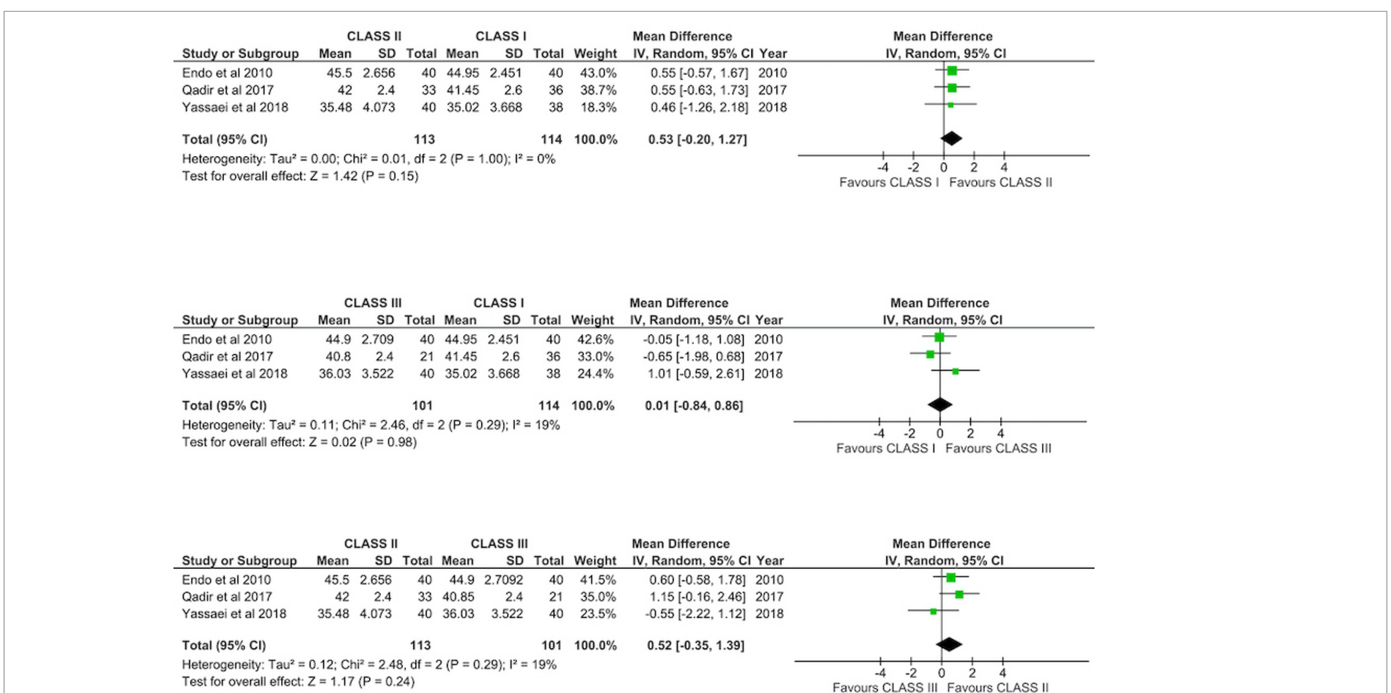

Figure 3. Forest plot comparing the maxillary sinus length between Class I, Class II and Class III sagittal malocclusion.
df, degrees of freedom; CI, confidence interval

size. The rest of the studies were graded as satisfactory due to lack of sample size calculation, lack of controlling the confounding factors such as age and sex,[6,9,18,21] and standardization of the growth pattern when the sagittal malocclusion was compared and vice versa.

The Class I and normodivergent data were considered normative in order to compare the dimensions between the groups. Prognathic maxilla associated with a Class II malocclusion could contribute to a greater sinus area. In the vertical dimension, the maxillary sinus area was greatest in the hyper-divergent followed by normodivergent and hypo-divergent growth patterns. The meta-analysis revealed no significant difference in the sinus volume between the growth patterns. Maxillary sinus size tends to be greater in males than in females.[24-27]

Study Limitations

Lack of published data with standardization of the growth pattern among the subjects classified into Class I, Class II or Class III, age and ethnicity.

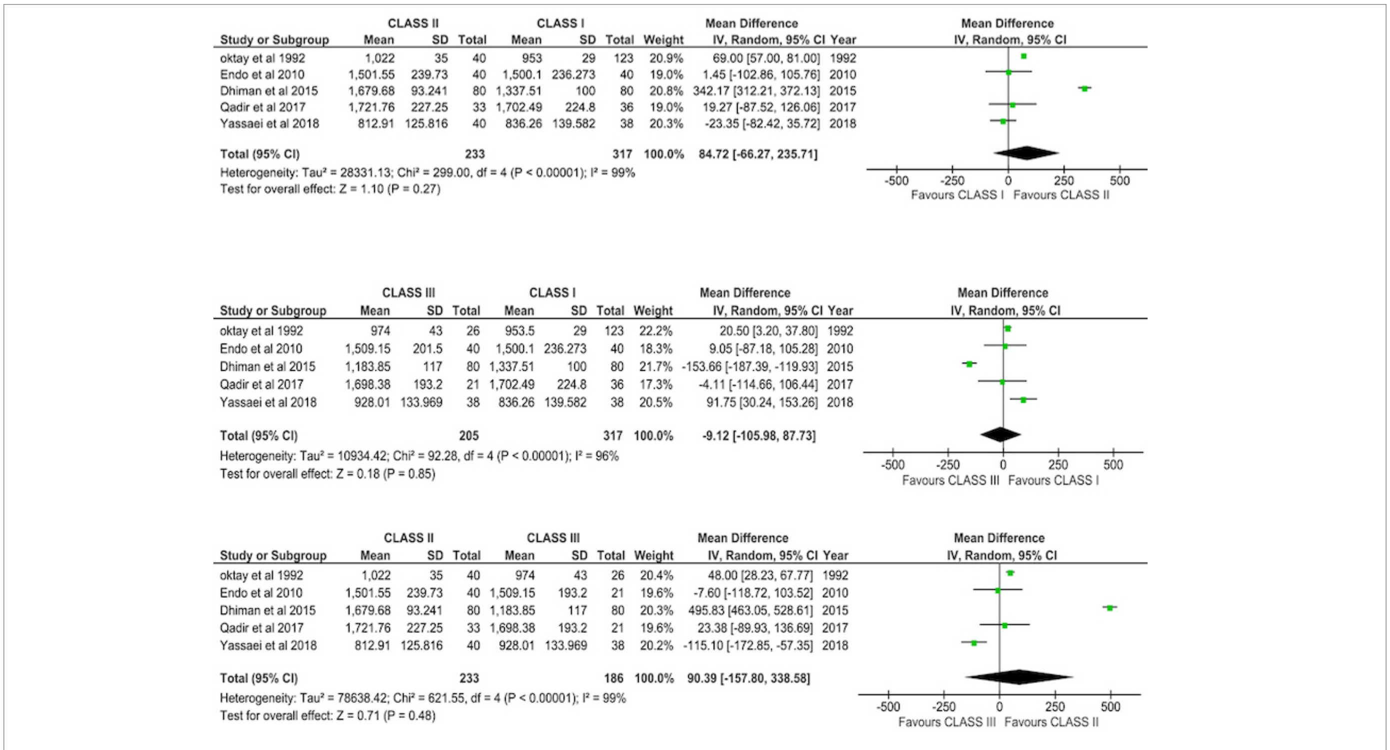

Figure 4. Forest plot comparing the maxillary sinus area between Class I, Class II and Class III sagittal malocclusion.
df, degrees of freedom; CI, confidence interval

Table 4. Maxillary sinus dimensions in vertical malocclusion

Author		Parameter			Outcome
		Hypo	Normo	Hyper	
Goymen at al.[7]	MSA	76.3±3.4	78.3±2	81.9±2.3	No significant difference
	MSH	37.5±1	38.4±0.6	37.7±0.8	
	MSW	32.8±0.7	33.9±0.6	35.1±0.7	
Shreshta et al.[16]	MSV	19042.94±75	20483.48±834	21305.89±7623.14	No effect
Al ani et al.[21]	MSA	1436.21±275.6	1524.41±260	1598±279.64	Height is greater in hyper-divergent
	MSH	37.15±4.57	40.18±4.33	42.1±4.4	
	MSL	38.47±3.93	37.81±3.47	37.8±3.4	
Oksayan et al.[5]	MSH	37.375±5.858	37.51±6.874	34.7±6.8	Length in low angle greater. Other dimensions show no difference
	MSL	37.7±4.769	35.6±5.95	35.6±4	
	MSW	28.34±4.603	27.48±5.627	26.5±5.0	
	MSV	15.2±4.51	13.8±5.412	12.7±4.5	
Yassaei et al.[6]	MSA, MSH and MSL	Correlation coefficient: SN- GoGn - R= -0.31, -0.071 and -0.376			MSA Is more in hypo-divergent group, MSH is more in hyper-divergent group, MSL is more in hypo-divergent group

MSH, maxillary sinus height; MSL, maxillary sinus length; MSA, maxillary sinus area; MSW, maxillary sinus width; MSV, maxillary sinus volume

CONCLUSION

Qualitative analysis of 12 studies done using the Modified Newcastle Ottawa (adapted for cross-sectional studies) scale reported 11 studies as being "satisfactory" and one study as "unsatisfactory". The GRADE approach indicated "low" overall certainty of evidence. Craniofacial form affects sinus dimensions with the vertical dimension appearing more critical.

Other Information

Protocol and Registration

This systematic review was conducted and reported following the PRISMA2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analysis).[28] The proposal was registered on the International Prospective Register of Systematic Reviews titled "Evaluation of maxillary sinus dimensions in

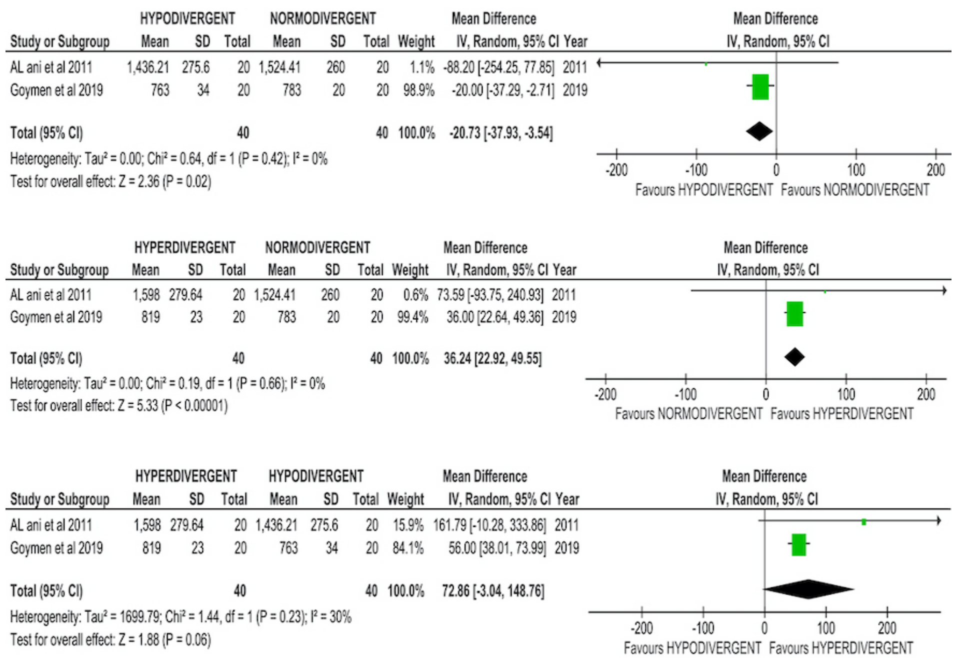

Figure 5. Forest plot comparing the maxillary sinus area between normo-divergent, hypo-divergent and hypo-divergent growth pattern.
df, degrees of freedom; CI, confidence interval

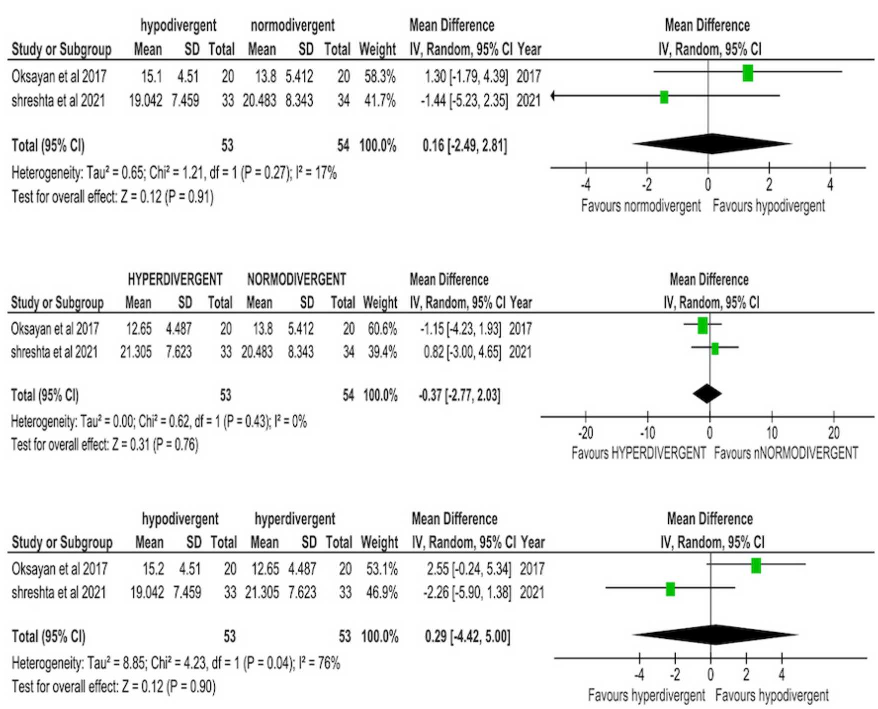

Figure 6. Forest plot comparing the maxillary sinus volume between normo-divergent, hypo-divergent and hyper-divergent growth pattern.
df, degrees of freedom; CI, confidence interval

different craniofacial patterns: A systematic review and meta-analysis" (CRD42021229438).

Ethics

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - R.C., P.R., V.K., S.P.; Design - R.C., P.R.; Data Collection and/or Processing - R.C., P.R.; Analysis and/or Interpretation - R.C., P.R., V.K., S.P.; Writing - R.C., V.K., S.P.; Critical Review - V.K., S.P.

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