The relationship of medial sigmoid depression and sigmoid notch morphology with vertical and sagittal growth patterns in Turkish population

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SUMMARY

Medial sigmoid depression (MSD) is an anatomical variation located just below the deepest point of the sigmoid notch (SN). The etiology of MSD is unknown. It has been reported that increased maximum bite force affects the occurrence of MSD, and vertical growth pattern affects SN morphology. The aim of this study was to investigate the effects of these malocclusions on the presence and morphology of MSD and SN, since bite force can change with vertical and sagittal growth patterns. This is the first study to investigate the effects of vertical growth pattern on the presence and morphology of MSD, and the effects of sagittal growth pattern on SN morphology. Panoramic and lateral cephalometric radiographs of a total of 634 (427 female, 207 male) patients aged from 18 to 35 years (mean 19.58) were included in this retrospective study. MSD and SN shapes, SN depth and width were evaluated on panoramic radiographs. Mann Whitney-U, Kruskal-Wallis and Chi-square tests were used for data analysis.

Sagittal and vertical growth patterns were not significantly associated with the presence and shape of MSD ($p>0.05$). SN depth was greater in individuals with class III malocclusion, and both SN depth and width were lower in hyperdivergent individuals. There was no significant relationship between SN shapes and vertical and sagittal growth patterns ($p>0.05$). SN depth is affected by both vertical and sagittal growth pattern, and SN width is affected only by vertical growth pattern. The presence of MSD was not associated with growth pattern.

Key words: Medial sigmoid depression – Sigmoid notch – Vertical growth pattern – Skeletal malocclusion – Panoramic radiography

INTRODUCTION

The sigmoid notch (SN) is a deep gap above the mandibular ramus that separates the condyle and the coronoid process (Tassoker et al., 2017). Anterior to the deepest point of the sigmoid notch, there is an anatomical variation known as medial sigmoid depression (MSD) (Carvalho et al., 2001).

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Posterior and medial attachments of the temporal muscle are inserted into this area (Özkan and Sessiz Ak, 2021).

Although the exact etiology of MSD is unknown, it has been stated that it may be a developmental or congenital variation (Özkan and Sessiz Ak, 2021). In addition, there are various studies showing that the presence of MSD is associated with dental and skeletal sagittal malocclusions (Carvalho et al., 2001; Dalili and Mohtavipour, 2003; Sudhakar et al., 2014).

In one study, greater occurrence of MSD was reported in association with increased maximum bite force (Adisen et al., 2018). Since the MSD region is an attachment site for some temporal muscle fibers, a number of studies suggested that the presence of MSD may also be correlated with temporal muscle activity (Adisen et al., 2018; Storey, 1975). EMG (electromyography) studies have demonstrated that temporal muscle activity was lower in hyperdivergent patients and higher in hypodivergent patients compared to normodivergent subjects (García-Morales et al., 2003; Ueda et al., 1998). The sigmoid notch (SN) allows for the passage of the masseteric nerve and artery, which innervates and supplies nutrients to the masseter muscle, respectively (Ishwarkumar et al., 2019). To the best of our knowledge, there is only one study which investigated the relationship between SN morphology and vertical growth pattern, showing that hyperdivergent individuals have a more concave SN than normodivergent individuals (Ferrario et al., 1999). No study has been identified in the literature on the relationship between sagittal growth pattern and SN morphology and the association of vertical growth pattern with the presence and morphology of MSD.

Therefore, the aim of this study was to evaluate the relationship of MSD and SN with the vertical and sagittal growth patterns of the face.

MATERIALS AND METHODS

This retrospective study was approved by Sivas Cumhuriyet University Ethics Committee for Non-Invasive Studies (14.04.2021, No. 2021-04/49). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Due to the retrospective nature of this study, a signed informed consent was not required.

For this study, lateral cephalometric and panoramic radiographs taken before orthodontic treatment at Sivas Cumhuriyet University Faculty of Dentistry between January 2018 and January 2021 were used. A total of 634 radiographs were included in the study. The exclusion criteria were the presence of artifacts, positioning errors, cysts, any pathology involving the area of interest and patients with prior orthodontic treatment.

The Orthopantomograph OP200D (Instrumentarium Dental, Tuusula, Finland) device was used to obtain the panoramic radiographs. The radiographs were taken at 66 kVp, 10 mA dose values and in P1 mode, including the temporomandibular joint. Lateral cephalometric radiographs were taken using Ortoceph OC200D (Instrumentarium Dental, Tuusula, Finland) device at dose parameters of 85 kVp and 13 mA.

Images were reviewed on a 8 GB RAM computer with a 23.6-inch Full HD IPS LED screen, Intel i5 processor, Windows 7 operating system and Cliniview 10.1 software in a semi-lit and quiet room. Measurements and examinations on all radiographs were examined by a researcher with 4 years of experience. Intra-observer agreement was assessed by evaluating 158 (25%) randomly selected radiographs two weeks apart.

ANB and SN-GoGn angles were used to determine sagittal and vertical skeletal patterns on cephalometric radiographs. Sagittal relationships of the jaws were classified as Class I (0º<ANB<4º), Class II (ANB>4º) and Class III (0º<ANB). The vertical growth pattern was classified as hypodivergent (SN-GoGn<28º), normodivergent (28º<SN-GoGn<36º) and hyperdivergent (SN-GoGn>36º) (Schudy, 1965). MSD location was evaluated separately for the right and left ramus, and MSD shapes were classified as semilunar, teardrop, circular, and triangular, as described by Carvalho et al. (2001) (Fig. 1).

SN width (SNW) and SN depth (SND) measurements were made on panoramic radiographs as

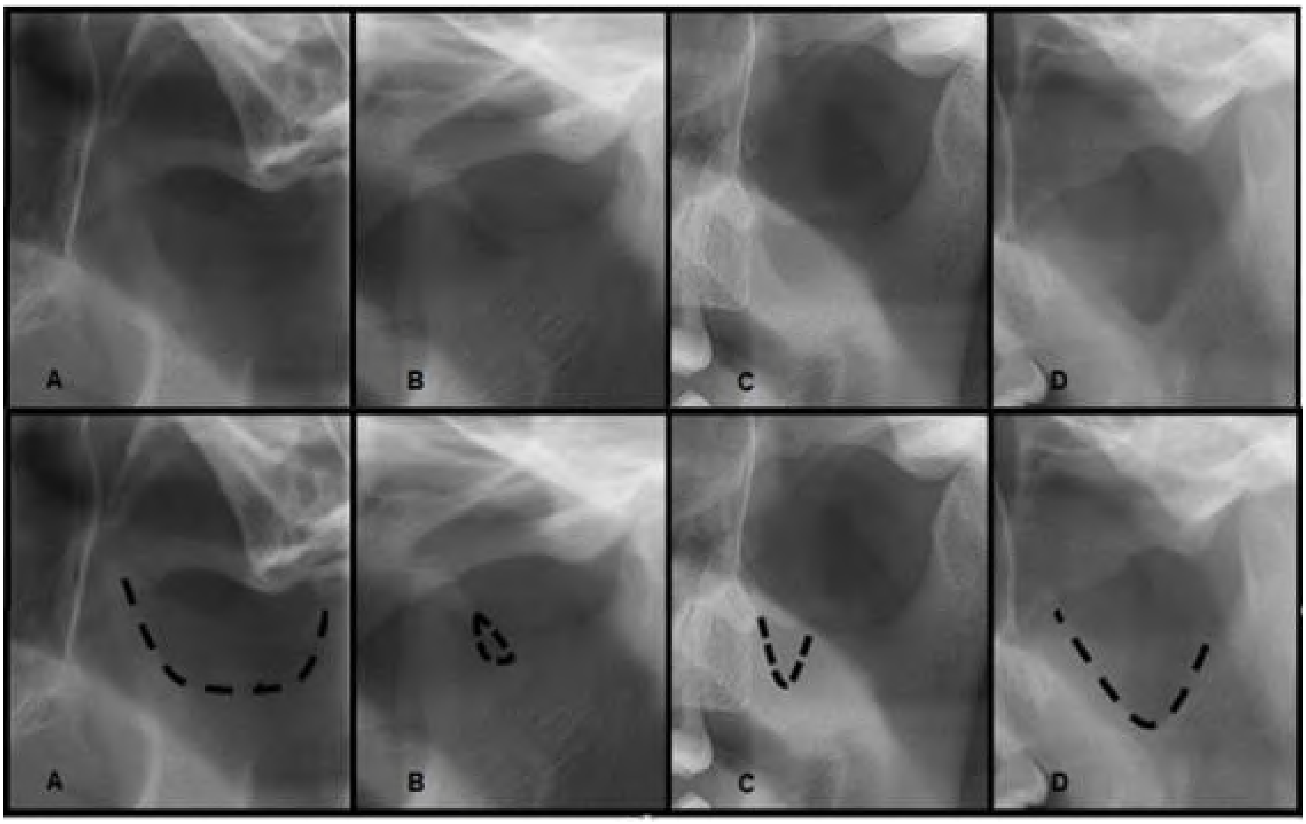

Fig. 1.- MSD Shapes. **A**: Semilunar, **B**: Circular, **C**: Teardrop, **D**: Triangular.

millimeters (mm). SNW was considered as the distance between the highest points of the condyle and coronoid process. SND was measured as the length of the perpendicular line drawn from the SN width line to the deepest point of SN (Fig. 2).

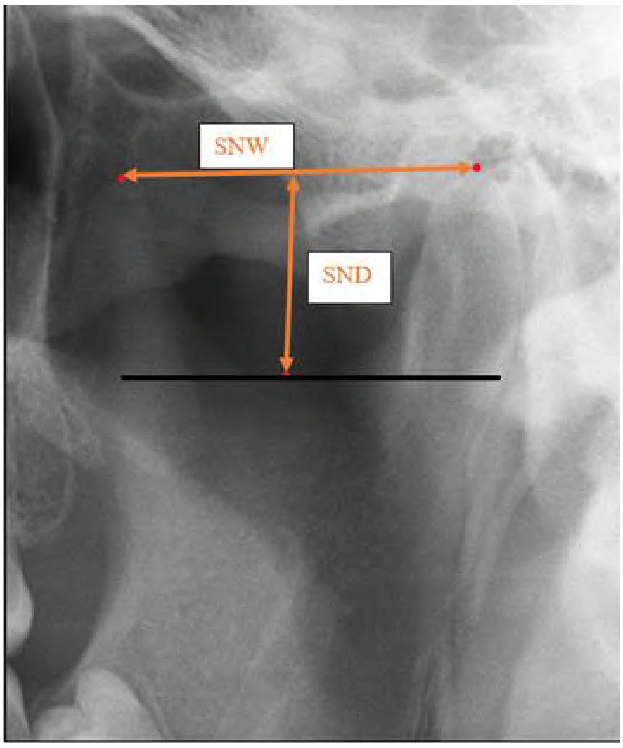

Fig. 2.- Measurement of SN depth (SND) and SN width (SNW).

SN morphology was classified as round, wide and sloping, as reported by Shakya et al. (2013) (Fig. 3).

Statistical analysis

The study data were analyzed using SPSS software package, version 22.0 (IBM Corp., Armonk, NY, USA). Chi-square test was used for categorical variables and Kruskal-Wallis test for numerical data. Pairwise comparisons were made using Dunn's test. Mann-Whitney U test was used to examine the distribution of measurements by sex. Intra-observer agreement was assessed using Kappa statistics and Intra-class Correlation Coefficient. A p value lower than 0.05 was considered statistically significant.

RESULTS

The mean age of 634 patients included in the study was 19.58 ± 3.58 years (mean ± SD). 427 (67.4%) individuals were female and 207 (32.6%) were male. Intra-observer agreement was found to be excellent (0.852-0.988) for categorical and numerical variables.

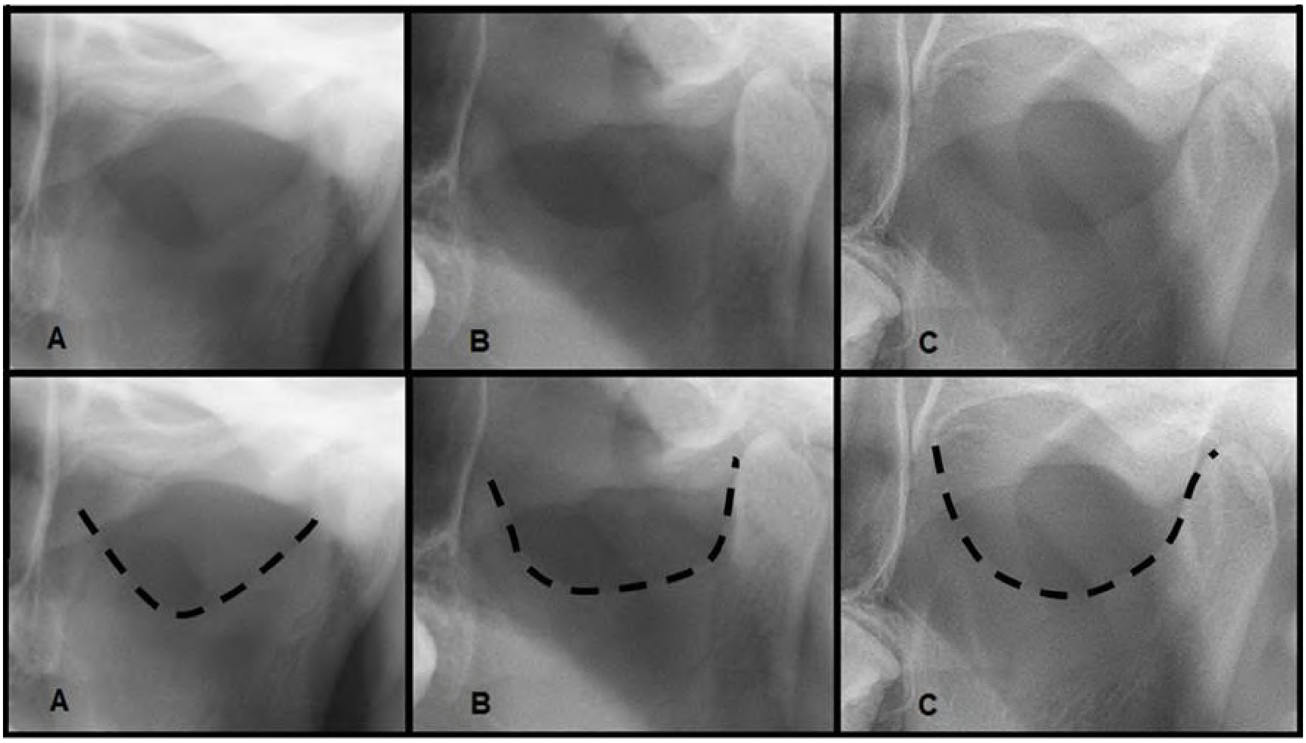

Fig. 3.- SN shapes. **A**: Sloping, **B**: Wide, **C**: Round.

When the vertical growth pattern was examined on cephalometric radiographs, hypodivergent growth pattern was observed in 142 (22.4%) individuals, normodivergent growth pattern in 251 (39.6%) individuals and hyperdivergent growth pattern in 241 (38%) individuals (Table 1). With regard to sagittal growth pattern, class-I relationship was observed in 298 (47%) individuals, class-II relationship in 238 (37.5%) individuals and class-III relationship in 98 (15.5%) individuals.

MSD was detected in 138/634 (21.8%) radiographs included in the study. The presence of MSD was not significantly associated with sex and sagittal/vertical growth patterns (p>0.05) (Table 1). With respect to MSD location, unilateral location was more common, and sex x and sagittal/vertical growth pattern did not show an effect on unilateral and bilateral location (p>0.05) (Table 1).

Among four MSD shapes (semilunar, triangular, circular and teardrop), semilunar shape was the most common (46.3%), followed by triangular (29.2%), circular (13.6%) and teardrop (10.7%) shapes, respectively (Table 2). MSD shape was not significantly associated with sex and sagittal/vertical growth pattern (p>0.05) (Table 2).

Table 1. MSD presence and location by sex and sagittal/vertical growth pattern

	Present	Unilateral Right	Unilateral Left	Bilateral	p
Male (n=207)	37 (17.9%)	9 (4.3%)	12 (5.8%)	16 (7.7%)	0.121
Female (n=427)	101 (%23.7)	32 (7.5%)	18 (4.2%)	51 (11.9%)	
Hypodivergent (n=142)	32 (22.5%)	10 (7%)	10 (7%)	12 (8.5%)	0.651
Normodivergent (n=251)	51 (20.3%)	17 (6.8%)	9 (3.6%)	25 (10%)	
Hyperdivergent (n=241)	55 (22.8%)	14 (5.8%)	11 (4.6%)	30 (12.4%)	
Class I (n=298)	58 (19.5%)	17 (5.7%)	14 (4.7%)	27 (9.1%)	0.741
Class II (n=238)	60 (25.2)	17 (7.1%)	13 (5.5%)	30 (12.6%)	
Class III (n=98)	20 (20.4%)	7 (7.1%)	3 (3. %1)	10 (10.2%)	
Total (n=634)	138 (21.8%)	41 (6.5%)	30 (4.7%)	67 (10.6%)	

Chi-square test
**Statistically significant if p<0.05*

Table 2. Distribution of MSD shapes by sex and sagittal/vertical growth pattern

		Semilunar	Triangular	Circular	Teardrop	p
Male (n=207)	Right	17 (68%)	4 (16%)	1 (4%)	3 (12%)	0.071
	Left	14 (50%)	5 (17.9%)	6 (21.4%)	3 (10.7%)	0.355
Female (n=427)	Right	37 (44.6%)	29 (34.9%)	12 (14.5%)	5 (6%)	0.071
	Left	27 (39.1%)	22 (31.9%)	9 (13%)	11 (15.9%)	0.355
Hypodivergent (n=142)	Right	14 (63.6%)	5 (22.7%)	2 (9.1%)	1 (4.5%)	0.863
	Left	9 (40.9%)	7 (31.8%)	3 (13.6%)	3 (13.6%)	0.791
Normodivergent (n=251)	Right	19 (45.2%)	15 (35.7%)	5 (11.9%)	3 (7.1%)	0.863
	Left	14 (41.2%)	8 (23.5%)	8 (23.5%)	4 (11.8%)	0.791
Hyperdivergent (n=241)	Right	21 (47.7%)	13 (29.5%)	6 (13.6%)	4 (9.1%)	0.863
	Left	18 (43.9%)	12 (29.3%)	4 (9.8%)	7 (17.1%)	0.791
Class I (n=298)	Right	21 (47.7%)	15 (34.1%)	5 (11.4%)	3 (6.8%)	0.924
	Left	18 (43.9%)	12 (29.3%)	2 (4.9%)	9 (22%)	0.152
Class II (n=238)	Right	26 (55.3%)	12 (25.5%)	5 (10.6%)	4 (8.5%)	0.924
	Left	17 (39.5%)	13 (30.2%)	10 (23.3%)	3 (7%)	0.152
Class III (n=98)	Right	7 (41.2%)	6 (35.3%)	3 (17.6%)	1 (5.9%)	0.924
	Left	6 (46.2%)	2 (15.4%)	3 (23.1%)	2 (15.4%)	0.152
Total (n=1264)		95 (46.3%)	60 (29.2%)	28 (13.6%)	22 (10.7%)	

Chi-square test.
**Statistically significant if p<0.05*

SND and SNW were significantly associated with vertical growth pattern on both right and left sides (p<0.05). Right and left SND were greatest in hypodivergent individuals, followed by normodivergent and hyperdivergent individuals, respectively (p<0.05).

When SNW measurements were compared, it was seen that hyperdivergent individuals had shorter SNW than hypodivergent individuals (p<0.05) (Table 3).

There was a significant relationship between sagittal growth pattern and SND (p<0.05), and class-III individuals had deeper SN than class-II individuals (p<0.05). No significant association was found between sagittal growth pattern and SNW (p>0.05) (Table 3). When the morphometric measurements (SND and SNW) were compared between the sexes, males showed higher values for all parameters (p<0.05) (Table 3).

There was no statistically significant difference among SN shapes in terms of vertical and sagittal growth patterns (p>0.05). SN morphology was round in 64.2%, wide in 19.8% and sloping in 16% of the individuals. Round type was more common in males (69.1%) and wide type was more common in females (22.3%), and this difference was significant for right SN (p<0.05) (Table 4).

DISCUSSION

Studies conducted in different populations reported a widely variable prevalence of MSD, ranging from 5% to 70% (Carvalho et al., 2001; Divya and Mahima, 2006; Honing, 1991; Özkan and Sessiz-Ak, 2021). Previous studies have shown that the presence of MSD is much higher on dry human mandibles than on panoramic radiographs (Byung-Cheol, 1991; Carvalho et al., 2001; Divya and Mahima, 2006; Langlais et al., 1983). While Langlais et al. (1983) explained this finding by the fact that the MSD region may not always be imaged due to focal trough of the panoramic radiography device, Carvalho et al. (2001) argued that the difference in anatomical, and radiographic examinations may be due to the inability to adequately visualize the relatively shallow depressions rather than the image layer. However, it has also been suggested that this may be caused by superposition of anatomical structures such as the lateral

Table 3. Morphometric parameters by sex and sagittal and vertical growth patterns

	SN Depth (SND)		SN Width (SNW)	
	Right	Left	Right	Left
Male	13.03±1.98	13.54±2.40	28.85±3.20	28.77±4.30
Female	12.53±1.94	12.64±1.87	27.98±3.24	27.68±3.33
p#	**<0.001***	**<0.001***	**0.004***	**<0.001***
Hypodivergent	13.48±1.73	13.40±1.76	28.87±3.03	28.61±4.03
Normodivergent	12.84±1.84	13.03±2.05	28.72±3.17	28.24±3.59
Hyperdivergent	12.33±2.13	12.54±2.25	27.41±3.30	27.49±3.57
p§	**<0.001***	**<0.001***	**<0.001***	**0.008***
Class I	12.91 2.16	13.00 2.10	28.34 3.44	28.13 3.54
Class II	12.47 1.61	12.63 2.14	28.32 2.93	27.88 3.63
Class III	13.16 2.13	13.42 1.86	27.86 3.38	28.13 4.32
p§	**0.003***	**<0.001***	0.229	0.830

 # Mann-Whitney U test
§ Kruskal-Wallis Test
** Statistically significant if p<0.05*

pterygoid plate, air space of the nasopharynx or soft palate (Byung-Cheol, 1991). Although the use of panoramic radiography allows a larger sample size to be studied, it may have led to underestimation of the MSD prevalence in the current study as well. However, since this will affect all groups similarly in terms of vertical (hyperdivergent, normodivergent, hypodivergent) and sagittal growth patterns (classes I, II, III), it is believed that its effect on the results would be minimal. The use of CBCT in future studies would provide more valid results in terms of true MSD prevalence.

Table 4. SN shapes by sex and sagittal/vertical growth pattern

		Round	Sloping	Wide	p
Male (n=207)	Right	148 (71.5%)	32 (15.5%)	27 (13%)	0.008*
	Left	138 (66.7%)	35 (16.5%)	34 (16.4%)	0.340
Female (n=427)	Right	262 (61.4%)	65 (15.2%)	100 (23.4%)	0.008*
	Left	265 (62.1%)	71 (16.7%)	91 (21.3%)	0.340
Hypodivergent (n=142)	Right	93 (65.5%)	21 (14.8%)	28 (19.7%)	0.646
	Left	93 (65.5%)	25 (17.6%)	24 (16.9%)	0.819
Normodivergent (n=251)	Right	157 (62.5%)	45 (17.9%)	49 (19.5%)	0.646
	Left	158 (62.9%)	44 (17.5%)	49 (19.5%)	0.819
Hyperdivergent (n=241)	Right	160 (66.4%)	31 (12.9%)	50 (20.7%)	0.646
	Left	152 (63.1%)	37 (15.4%)	52 (21.6%)	0.819
Class I (n=298)	Right	189 (63.4%)	47 (15.8%)	62 (20.8%)	0.580
	Left	183 (61.4%)	53 (17.8%)	62 (20.8%)	0.657
Class II (n=238)	Right	151 (63.4%)	36 (15.1%)	51 (21.4%)	0.580
	Left	154 (64.7%)	41 (17.2%)	43 (18.1%)	0.657
Class III (n=98)	Right	70 (71.4%)	14 (14.3%)	14 (14.3%)	0.580
	Left	66 (67.3%)	12 (12.2%)	20 (20.4%)	0.657
Total (n=1268)		813 (64.1%)	203 (16%)	252 (19.9%)	

Chi-square Test
**Statistically significant if p<0.05*

In a study by Özkan and Sessiz-Ak (2021) on 1000 panoramic radiographs from a representative Turkish population, the prevalence of MSD was reported at 23.4%, with a significant increase in the prevalence with age (p<0.05). In the present study, the prevalence of MSD was 21.8%, which is similar to that reported by Özkan and Sessiz-Ak (2021). The large differences among populations with regard to the presence of MSD suggest that genetic factors may also be involved. In this study, the age range was narrow, precluding the ability to examine the relationship between MSD and age.

The association between temporal muscle activity and the vertical growth pattern of the face has been reported in the literature, with EMG studies showing reductions in temporal muscle activity and maximum bite force in hyperdivergent individuals, and increases thereof in hypodivergent individuals (García-Morales et al., 2003; Ueda et al., 1998). It has also been stated that muscle activity may affect the presence and shape of the MSD, due to the attachment of some of the temporal muscle fibers to the MSD area (Adisen et al., 2018; Al-Sadhan, 2021; Storey, 1975). The aforementioned results led to the question as to whether MSD occurs more commonly in hypodivergent patients with greater temporal muscle activity.

The present study attempted to find an answer to this question and no significant association was found between the vertical growth of the face and the presence of MSD. This suggests that, contrary to what is expected, temporal muscle activity may not strongly affect the shape of MSD. However, the significant increase in the prevalence of MSD in individuals with high maximum bite force (Adisen et al., 2018) suggests that environmental factors and masticatory forces may also be involved in the occurrence of MSD.

Very few studies in the literature evaluated the relationship between the presence of MSD and sagittal skeletal and dental malocclusions and yielded differential results (Carvalho et al., 2001; Dalili and Mohtavipour, 2003; Sudhakar et al., 2014; Adisen et al., 2018) In only one study, the prevalence of MSD was found to be higher in individuals with class II malocclusion, which is related to the sagittal growth pattern (p<0.05) (Carvalho et al., 2001), with no significant associations found in other studies (Dalili and Mohtavipour, 2003; Sudhakar et al., 2014; Adisen et al., 2018). However, in the current study, the presence of MSD was more common in individuals with skeletal class-II malocclusion (p>0.05), albeit non-significantly. In addition, the presence of MSD was not be associated with vertical malocclusion and sex, and a comparison could not be made because this is the first study to investigate this relationship. In the presence of MSD, this should be taken into consideration before orthognathic surgery, because since the bone structure in this region is very thin, there is an increased risk of complications, and the fixation of the fracture line cannot be achieved.

Carvalho et al. (2001) reported that the most common MSD morphology is the triangular shape. Contrastingly, separate studies have reported that the most common form of MSD is the semilunar type (Dalili and Mohtavipour, 2003; Divya and Mahima, 2006; Sudhakar et al., 2014; Adisen et al., 2018). Sudhakar et al. (2014) reported that there was no significant relationship between MSD shapes and sagittal growth pattern in their study on 300 panoramic radiographs. In line with former studies, the most common MSD morphology was semilunar type in the present study, with no significant association of MSD shapes with sex, and vertical and sagittal growth patterns.

To the best of our knowledge, there is only one study that investigated the relationship between SN morphology and vertical growth pattern. In their morphological study using Fourier analysis on lateral cephalometric radiographs of 45 girls, Ferrario et al. (1999) reported that more concave SN was observed in hyperdivergent individuals. In contrast, SN shapes did not differ significantly in relation to vertical growth pattern in the current study (p>0.05). On the other hand, as shown by SND and SNW measurements, sigmoid notches were significantly shallower and narrower in hyperdivergent individuals and significantly deeper and wider in hypodivergent individuals, which are consistent with the findings reported by Ferrario et al. (1999). Additionally, it was observed that the morphometric properties of SN are affected by the vertical growth pattern to a greater extent compared to its morphological features.

In the present study, no association was found between the SN morphology and the sagittal growth pattern, and a comparison could not be made due to lack of similar studies. However, SND was greater in individuals with class III malocclusion ($p<0.05$). This may be due to the increased condyle height in class III individuals as demonstrated by various studies (Hasebe et al., 2019; Noh et al., 2021).

In their study on 149 panoramic radiographs and 51 dry mandibles from the South African and Indian populations, Ishwarkumar et al. (2019) reported that the width of SN was greater in males ($p<0.05$). In a study from Saudi Arabia on 240 panoramic radiographs, males (14.01 mm) were found to have a deeper sigmoid notch than females (13.75 mm) ($p<0.05$) (Al-Gunaid, 2020). Likewise, in the current study, SND and SNW were found to be significantly higher in males ($p<0.05$), and to the best of our knowledge, this is the first study to report the dimensions of SN in the Turkish population.

CONCLUSION

In conclusion, SN depth is affected by both vertical and sagittal growth patterns, and SN width is affected only by vertical growth pattern. The presence of MSD was not found to be associated with growth pattern. Further studies in which the relationship of MSD with vertical and sagittal growth patterns is investigated in a wider range of age groups and muscle activities are evaluated using EMG would provide valuable findings.

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Author Contributions

All authors have contributed to writing and reviewing the manuscript, conceptualizing of the work. In addition, ACG acquired and analyzed data; DY and IE overviewed the coordination of the work.

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