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Prevalence and extension of the anterior loop of the mental nerve in different populations and CBCT imaging settings: A systematic review and meta-analysis

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ABSTRACT

Purpose: This study aimed to identify the prevalence and extension of the anterior loop (AL) of the mental nerve in different populations and according to different cone-beam computed tomography (CBCT) imaging settings.
Materials and Methods: Medline/PubMed, Embase, Scopus, Web of Science, and ProQuest were searched. The main inclusion criterion was ALs evaluated in CBCT images. The quality of studies was assessed with the Joanna Briggs Institute risk of bias checklist. Subgroup analyses were conducted for sex, side, continent, voxel size, field of view, and type of CBCT-reconstruction images with a random-effects model.
Results: Sixty-three studies with 13,743 participants (27,075 hemimandibles) were included. An AL was found in 40.6% (95% CI: 32.8%-48.9%, $P<0.05$) of participants and 36.0% (95% CI: 27.5%-45.5%, $P<0.05$) of hemimandibles, in 34.9% (95% CI: 25.1%-46.2%, $P<0.05$) of males and 34.5% (95% CI: 23.5%-47.4%, $P<0.05$) of females. The average length of ALs was 2.39 mm (95% CI: 2.07-2.70 mm, $P<0.05$). Their extension was 2.13 mm (95% CI: 1.54-2.73 mm, $P<0.05$) in males and 1.85 mm (95% CI: 1.35-2.36 mm, $P<0.05$) in females. Significant differences were observed regarding the prevalence and length of ALs among continents and for its measured length on different CBCT-reconstruction images, but not between other subgroups.
Conclusion: AL was a relatively common finding. The voxel size and fields of view of CBCT devices were adequate for assessing AL; however, a 2-mm safety margin from anatomical structures (such as the AL) could be recommended to be considered when using CBCT imaging. ***(Imaging Sci Dent 2022; 52: 141-53)***

KEY WORDS: Inferior Alveolar Canal; Mandibular Nerve; Cone-Beam Computed Tomography; Systematic Review

Introduction

Intra-oral surgery commonly results in postoperative side effects and complications, one of the most serious of which is unintentional injury to the inferior alveolar nerve (IAN).[1] The mental portion of the IAN is categorized into straight (linear) and perpendicular portions, as well as the anterior loop (AL).[2] Predicting the position of an AL is essential in treatment planning for surgical procedures involving flap reflection, osteotomy, bone harvesting, and implant fixture placement in the anterior mandible.[3,4] Neurosensory disturbances and hemorrhage are the most common complications of these surgical procedures.[5,6] A recent systematic review on neurosensory disturbances after mandibular implant treatment procedures showed that the incidence of sensory disturbances ranged from 6.5% to 40%, and implants placed in the anterior region had a greater risk for nerve damage.[7]

Various approaches have been suggested for avoiding complications, such as direct visualization during surgery; identification of its location on periapical or panoramic radiography, magnetic resonance imaging, computed tomography, or cone-beam computed tomography (CBCT);

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Table 1. Search strategy sample in PubMed.

(((((((((((((((((("Mandibular Nerve"[Mesh]) OR ('mandibular nerve'[Text Word])) OR ('mandible branch'[Text Word])) OR ('mandible nerve'[Text Word])) OR ('mandible ramus'[Text Word])) OR ('mandibular branch'[Text Word])) OR ('mandibular branch, trigeminal nerve'[Text Word])) OR ('mandibular nerve'[Text Word])) OR ('mandibular ramus'[Text Word])) OR ('nerve, mandibular'[Text Word])) OR ('nervus mandibularis'[Text Word])) OR ('ramus mandibulae'[Text Word])) OR ('ramus mandibularis nervi trigemini'[Text Word])) OR ('trigeminal nerve mandibular branch'[Text Word])) OR ('trigeminus nerve mandibular branch'[Text Word])) OR ('anterior loop'[Text Word])) OR ('inferior alveolar nerve'[Text Word])) OR ('nervus alveolaris inferior'[Text Word])) AND (((((((((((((CBCT[Text Word]) OR ('cone beam computed tomography'[Text Word])) OR ('cone beam ct'[Text Word])) OR ('cone beam computed tomography'[Text Word])) OR ('cone beam computerized tomography'[Text Word])) OR ('cone-beam computed tomography'[Text Word])) OR ('spiral cone-beam computed tomography'[Text Word])) OR ('volume ct'[Text Word])) OR ('volume computed tomography'[Text Word])) OR ('volumetric ct'[Text Word])) OR ('volumetric computed tomography'[Text Word])) OR ('three dimensional imaging'[Text Word])) OR ("Cone-Beam Computed Tomography"[Mesh]))

or maintaining an average safety distance, which may vary among different individuals or ethnicities.[8,9] Currently, the most accurate available modality for dentists to quantitatively determine the presence of AL is high-resolution CBCT.[10] According to the literature, major variations have been reported in the prevalence and length of the AL; its prevalence is reported to range from 7.7%[11] to 95.2%[12] and its length from 0.25 mm[13] to 19 mm.[11] It has been suggested that sex, ethnicity, and age differences may exist;[8,9,14] therefore, evaluating the prevalence and length of AL and determining a precise and safe distance from it in different population subgroups can be of clinical significance.

To the authors' best knowledge, a considerable number of publications exist on this topic and a meta-analysis has previously been conducted on the overall prevalence of AL.[15] However, no meta-analysis has assessed the prevalence and length of the AL according to sex, continent, and side of the mandible, or while taking into account the effect of imaging-related factors such as various types of CBCT-reconstruction images, voxel sizes, and fields of view at the side- and patient-based levels. The current systematic review and meta-analysis aimed to assess the prevalence and extension of the AL of the mental nerve in terms of different population-based characteristics and imaging settings in CBCT images.

Materials and Methods

The present study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[16] The study protocol was registered and published in the International Prospective Register of Systematic Reviews (PROSPERO) (registration ID: CRD42020195984). The study question was: "What is the prevalence and extension of AL of the mental nerve in terms of different population characteristics and CBCT imaging settings?"

Article screening was performed using the following eligibility criteria. The inclusion criteria were defined in the CoCoPop frame:[17] 1) condition: prevalence and extension of the AL of the mental nerve in terms of different population characteristics and CBCT imaging settings; 2) context: CBCT-reconstruction radiographs; and 3) population: patients from whom CBCT images were taken for different therapeutic purposes.

All animal studies, abstracts, unpublished articles, reviews, and studies conducted on cadavers or patients with systemic diseases that could affect bone metabolism, anatomic abnormalities, or a history of trauma in the mandible were excluded. Articles reporting opposing and contradictory results in different parts of their texts were also excluded. No language restrictions were imposed.

A thorough search was executed (by MH) in Medline/PubMed, Web of Science, Scopus, Embase, and ProQuest Dissertations & Theses for articles published up to November 23, 2020. The search strategies were designed using modifications or the combinations of the free keywords and those obtained from the MeSH database of PubMed and the Emtree database of Embase through Boolean operators (AND, OR). The search strategy in the PubMed database is presented in Table 1. Google Scholar and the Open Gray database were also searched for existing gray literature relevant to the study's topic. Studies included in similar published systematic reviews and the references of the included articles in the present study were also searched to find relevant articles.

Two reviewers (MH and LG) independently carried out the screening process in 2 steps. First, some of the articles were excluded based on titles and abstracts. Next, the full texts of articles were thoroughly reviewed, and the articles that did not meet the eligibility criteria were ruled out. In case of disagreement, the third author (NE) was consulted to reach a consensus.

An extraction table was designed by assessing 15 studies included in the pilot phase of the extraction stage. After an

Table 2. Characteristics of studies reporting the prevalence of the anterior loop

Author	Country	Study population (patient/side)	Total population		Side	Sex (M/F)	
			Patient-based	Side-based	Right/left/bilateral	Patient-based	Side-based
Velasco-Torres et al.[1]	Spain	348/696	202	403*	209/194/–	–	–
Vujanovic-Eskenazi et al.[10]	Spain	82/–	40	–	–	–	–
de Brito et al.[11]	Brazil	90/180	7	26	–	–	–
Haghanifar et al.[12]	Iran	207/–	197	–	–	–	–
do Nascimento et al.[13]	Brazil	250/500	135	208	29/33/73	–	92/116
Apostolakis and Brown[14]	UK	93/186	–	91	–	–	–
Xie et al.[21]	China	1008/2016	147	212	41/41/65	–	–
Yang et al.[22]	China	412/824	–	771	–	–	312/459
Sinha et al.[23]	India	1000/–	97	131	36/27/34	58/39	–
do Carmo Oliveira et al.[24]	Brazil	202/404	48	96*	50*/46*/–	–	40*/56*
Phraisukwisarn et al.[25]	Thailand	219/250	38*	161	–/–/31	–	64/97
Lu et al.[26]	US	366/732	–	624	314/310/–	–	314/310
Chen et al.[27]	US/Taiwan	200/–	–	–	–	–	–
von Arx et al.[28]	Switzerland	142/167	100	117	–	–	–
Krishnan et al.[29]	Australia	109/–	52	–	–	–	–
Vieira et al.[30]	Brazil	240/480	–	49	20/29/–	–	12/37
Shalash et al.[31]	Egypt	120/–	66	–	–	–	–
Abidullah et al.[32]	India	120/240	24	24	11/13/–	10/14	–
Genú et al.[33]	Brazil	143/286	27	37*	8/9/10	13/14	–
Siddiqui et al.[34]	India	193/386	72	72	34/38/–	42/30	42/30
Panjnoush et al.[35]	Iran	200/400	119	197	22/19/78	59/60	–
Karnasuta et al.[36]	Thailand	248/441	184	368*	198/170/–	74/110	162/206
Shokry et al.[37]	Saudi Arabia	67/–	59	–	–	–	–
Sakhdari et al.[38]	Iran	200/400	38	45*	16/15/7	–	–
do Couto-Filho et al.[39]	Chile	47/94	14	17*	7/4/3	–	–
Chen et al.[40]	China	60/–	23	–	–	–	–
Ritter et al.[41]	Germany	1010/–	313	–	–	174/137	–
Raju et al.[42]	United States	124/248	31	59	–/–/28	13/18	–
Prakash et al.[43]	India	90/–	45	–	–	15/30	–
Puri et al.[44]	India	80/–	42	–	–	–	–
Kastala et al.[45]	India	90/180	–	102	52/50/–	–	59*/43*
Chibber et al.[46]	India	60/–	32	–	–	–	–
Eren et al.[47]	Turkey	141/282	–	242	–	44/66	–
Dhumad and Saliem[48]	Iraq	90/180	27	65*	31/34/–	–	31/34
Demir et al.[49]	Turkey	279/558	–	332	168/164/–	167/165	–
Filo et al.[50]	Switzerland	694/1384	–	965	494/471/–	–	476/489
Wei et al.[51]	China	306/612	251*	415	214/201/–	–	195/220
Rodricks et al.[52]	India	200/400	115	128	102/74/115	102/74	–
Tofiño-Medina et al.[53]	Peru	80/–	–	–	–	–	–
Lee et al.[54]	South Korea	20/–	–	–	–	–	–
Dos Santos Oliveira et al.[55]	Brazil	174/348	–	240	120/120/–	–	–
Chappidi et al.[56]	India	250/500	–	100	38/62/24	–	59/41
Sahman and Sisman[57]	Turkey	494/988	141	217	40/25/76	–	124/93
Koivisto et al.[58]	United States	106/212	11	15	–	2/9	–
de Oliveira-Santos et al.[59]	Brazil	100/–	–	–	–	–	–
Kung et al.[60]	Taiwan	215/–	–	–	–	–	–

Table 2. Continued

Author	Country	Study population (patient/side)	Total population		Side	Sex (M/F)	
			Patient-based	Side-based	Right/left/bilateral	Patient-based	Side-based
Alyami et al.[61]	Saudi Arabia	149/298	–	37	20/17/–	–	–
Sridhar et al.[62]	India	146/292	26	28	11*/13*/2*	15/11	11*/17*
Goller Bulut and Köse[63]	Turkey	48/–	–	–	–	–	–
Kheir and Sheikhi[64]	Iran	180/360	59	122	17*/21*/42	–	63*/59*
Al-Mahalawy et al.[65]	Saudi Arabia	302/604	–	92	50/42/–	–	–
J et al.[66]	India	85/140	10	14	3/3/4	–	–
Roshene and Kumar[67]	India	30/–	–	–	–	–	–
Rosa et al.[69]	Brazil	326/–	–	–	–	–	–
Kajan and Salari[78]	Iran	84/168	–	62	33/29/–	21/19	–
Parnia et al.[79]	Iran	96/192	81	140	80/60/–	–	–
Marieiro et al.[80]	Brazil	82/–	11	–	–	–	–
Eachempati et al.[81]	Malaysia	99/198	–	60*	37/23/–	–	–
Moghddam et al.[82]	Iran	234/451	95	106	–/–/11	46/47	–
Gala et al.[83]	India	65/130	–	104	–	–	–
Wong and Patil[84]	Malaysia	100/–	94	–	–	–	–
Bosykh et al.[85]	Russia	400/800	37	74	37/37/–	–	60/14
Gupta et al.[86]	India	149/298	52	122	57/65/–	–	–

M: male, F: female

agreement was reached on the appropriateness of the extraction table, 2 authors (MH and LG) started the extraction process independently, and in cases of disagreement, the third author (NE) was consulted to reach a consensus. The extraction table reported AL prevalence based on total population, sex (male/female), side (right/left), and country, as reported in Table 2.

The Joanna Briggs Institute Critical Appraisal Checklist for Studies Reporting Prevalence Data[18] was used to assess the risk of bias independently by 2 reviewers (NE and MG). Both reviewers discussed any possible disagreement and reached a consensus. After completing the risk of bias assessment form for each study, the percentage of "yes" answers was obtained and used to quantify the existing bias. Bias was categorized into "high risk" (<50%), "moderate risk" (50% to 99%), and "low risk" (100%).

Statistical analysis

The fields of view were categorized into 3 subgroups according to Barbosa et al.[19] Meta-analyses were conducted (by MG) with Comprehensive Meta-Analysis (CMA) software, version 2. The prevalence of AL was considered a dichotomous variable and reported as relative risk. The length of AL was considered a continuous variable and reported as means and standard deviations. The significance level was considered as 5%. Heterogeneity was reported through the chi-square test (Cochrane Q), the related P-value (significance level: $P<0.05$), and the I^2 value. An I^2 value above 50% was considered to indicate high heterogeneity,[20] and if it was accompanied by design and methodological heterogeneity among the studies, a random-effects model was implemented. The heterogeneity Q-test was used to compare the subgroups through the amount of overlap existing among point estimates and their 95% confidence intervals. To decrease heterogeneity, according to the information in the literature, the prevalence and length data were subgrouped based on sex (male/female), side (right/left), continent, the type of CBCT-reconstruction images, voxel size, and field of view.

Results

Study selection

The search process resulted in 2,645 articles. After excluding duplications, 1,699 studies remained. No study was found from other sources. Following the first phase of screening, 1,599 studies were ruled out due to irrelevant titles or abstracts. A number of 70 studies went through a complete full-text evaluation, in which 7 were excluded and 63 articles met the eligibility criteria. The flow chart

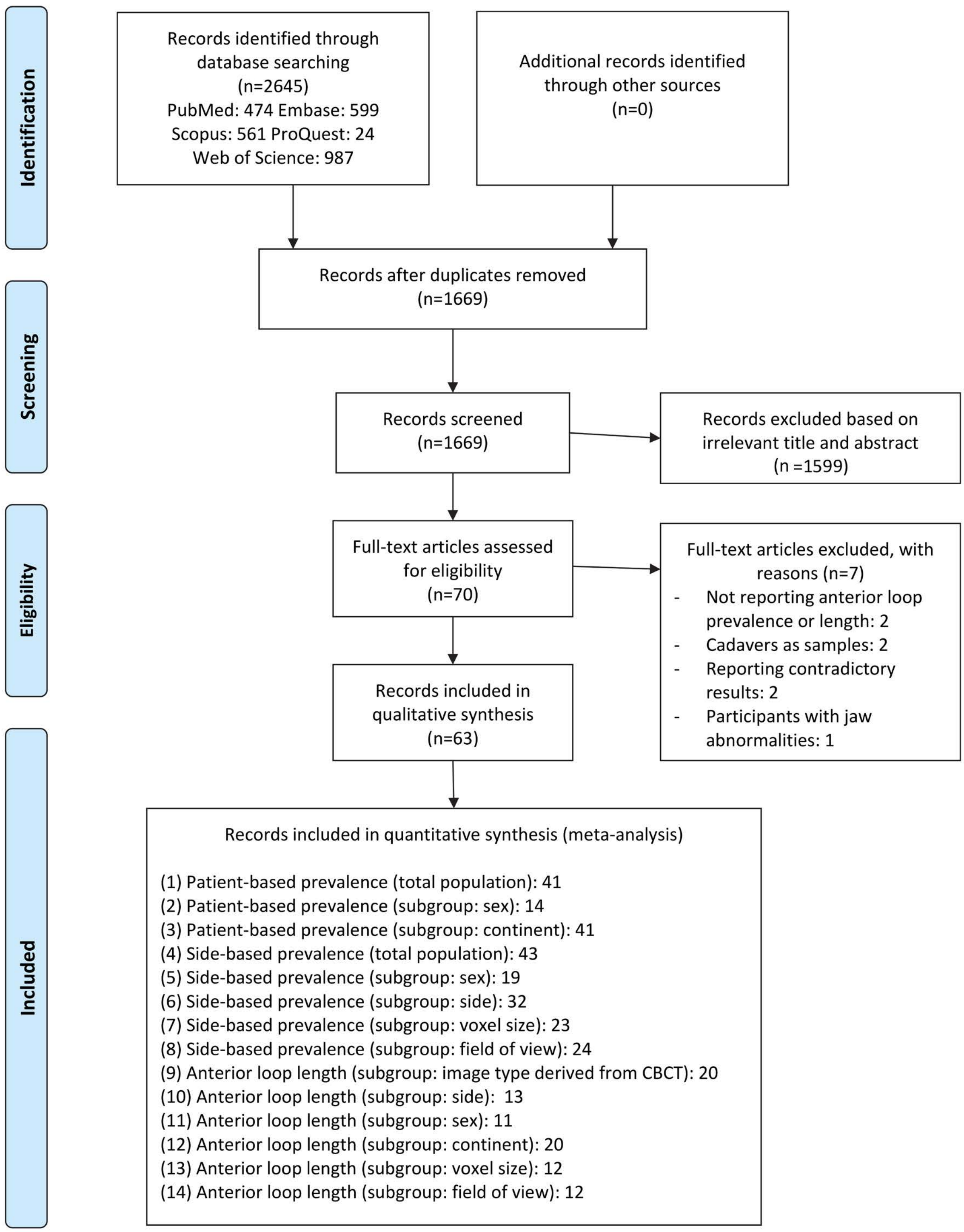

Fig. 1. PRISMA flow chart.

in Figure 1 presents the screening process according to the PRISMA guideline.

Study characteristics

An extraction table containing the characteristics of the included articles is presented in Table 2. Sixty-three studies with 13,743 participants (27,075 sides) satisfied the eligibility criteria and were ultimately included. Fifty-eight studies reported their sample sizes (12,256 participants) in terms of sex (5,829 males and 6,427 females). The distribution of countries in which the studies were conducted was as follows: 14 studies in India, 9 studies in Brazil, 7 studies

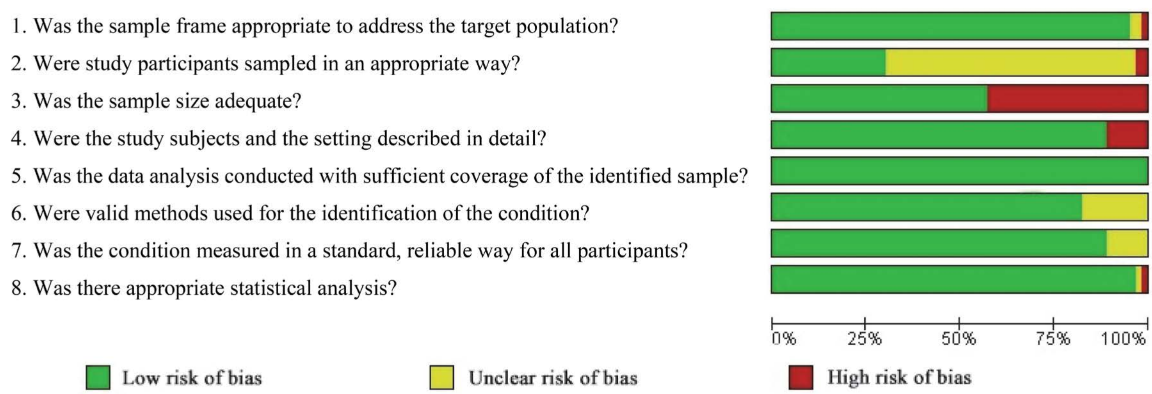

Fig. 2. Risk of bias assessment summary.

Table 3. Anterior loop length based on CBCT-reconstruction image types analyzed using a random-effects model

Subgroup	Study name	Mean	Standard error	Variance	95% confidence interval	*P*-value
Cross-sectional	do Nascimento et al.[13]	1.060	0.055	0.003	0.951-1.169	<0.05
	Apostolakis and Brown[14]	0.890	0.123	0.015	0.650-1.130	<0.05
	Yang et al.[22]	2.530	0.046	0.002	2.440-2.620	<0.05
	Phraisukwisarn et al.[25]	2.160	0.095	0.009	1.975-2.345	<0.05
	Siddiqui et al.[34]	3.660	0.235	0.055	3.200-4.120	<0.05
	Filo et al.[50]	1.160	0.033	0.001	1.096-1.224	<0.05
	Rodricks et al.[52]	0.440	0.044	0.002	0.353-0.527	<0.05
	Christopher et al.[66]	2.790	0.158	0.025	2.481-3.099	<0.05
	Eachempati et al.[81]	2.780	0.103	0.011	2.578-2.982	<0.05
	Total	1.927	0.300	0.090	1.339-2.515	<0.05
Panoramic	do Carmo Oliveira et al.[24]	2.200	0.105	0.011	1.994-2.406	<0.05
	Genu et al.[33]	3.140	0.205	0.042	2.737-3.543	<0.05
	Eren et al.[47]	3.150	0.110	0.012	2.935-3.365	<0.05
	Dhumad and Saliem[48]	3.140	0.114	0.013	2.916-3.364	<0.05
	Total	2.901	0.265	0.070	2.382-3.420	<0.05
Other	Velasco-Torres et al.[1]	1.960	0.049	0.002	1.864-2.056	<0.05
	Lu et al.[26]	1.460	0.050	0.003	1.362-1.558	<0.05
	Wei et al.[51]	3.300	0.059	0.003	3.185-3.415	<0.05
	Sahman and Sisman[57]	2.130	0.064	0.004	2.005-2.255	<0.05
	Sridhar et al.[62]	1.560	0.110	0.012	1.345-1.775	<0.05
	Kheir and Sheikhi[64]	2.510	0.124	0.015	2.267-2.753	<0.05
	Moghddam et al.[82]	2.770	0.152	0.023	2.473-3.067	<0.05
	Total	2.239	0.274	0.075	1.702-2.776	<0.05

in Iran, and 4 studies in each of the 3 countries of China, the United States, and Turkey. There were fewer than 4 studies conducted in other countries.

The countries with the largest sample sizes were India with 2,558, China with 1,786, Brazil with 1,607, Iran with 1,201, and Germany with 1,010 participants. These countries made up almost 60% of the total sample size. Other countries had sample sizes of less than 1,000.

The included studies reported the prevalence of AL in 2 ways: patient-based and/or side-based. Patient-based reporting considers a participant or a CBCT image of a complete mandible as a sample unit, whereas side-based reporting considers a hemimandible as a sample unit. For example, Xie et al.[21] reported that there were 147 subjects with ALs (patient-based); by adding 106 right-side and 106 left-side ALs, a total of 212 ALs were detected in the hemiman-

Table 4. Pooled estimates of the prevalence and length of anterior loops within different subgroups

Subgroup			No. of studies	Point estimate (95% confidence interval)	*P*-value	I^2 (%)	Heterogeneity *P*-value
Patient-based prevalence	Total	-	41	40.6% (32.8-48.9)	<0.05	97.6	<0.05
	Sex	Male	14	34.9% (25.1-46.2)	<0.05	97.6	<0.05
		Female	14	34.5% (23.5-47.4)	<0.05	95.0	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
	Continent	Asia	24	46.6% (34.1-59.4)	>0.05	98.11	<0.05
		Europe	7	44.2% (28.1-61.5)	>0.05	98.21	<0.05
		South America	6	22.4% (11.6-38.7)	<0.05	94.99	<0.05
		North America	2	16.8% (6.7-36.2)	<0.05	87.08	<0.05
		Africa	1	55.0% (46.0-63.7)	>0.05	-	-
		Australia	1	47.7% (38.5-57.1)	>0.05	-	-
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					<0.05
Side-based prevalence	Total	-	43	36.0% (27.5-45.5)	<0.05	99.18	<0.05
	Sex	Male	19	47.8% (34.9-60.9)	>0.05	98.11	<0.05
		Female	19	39.7% (27.0-54.0)	>0.05	98.64	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
	Side	Right	32	32.3% (22.8-43.7)	<0.05	98.70	<0.05
		Left	32	29.7% (21.0-40.2)	<0.05	98.60	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
	Voxel size	<0.3 mm	14	34.4% (21.6-49.8)	<0.05	99.01	<0.05
		≥0.3 mm	9	36.0% (16.5-61.7)	>0.05	99.60	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
	Field of view	Small	8	28.2% (15.1-46.4)	<0.05	98.49	<0.05
		Medium	7	36.0% (11.7-70.5)	>0.05	99.46	<0.05
		Large	9	57.7% (37.6-75.5)	>0.05	99.49	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
Anterior loop length	CBCT-reconstruction image type	Cross-sectional	9	1.92 mm (1.33-2.51)	<0.05	99.50	<0.05
		Panoramic	4	2.90 mm (2.38-3.42)	<0.05	94.44	<0.05
		Other planes	7	2.23 mm (1.70-2.77)	<0.05	99.06	<0.05
		Total	20	2.39 mm (2.07-2.70)	<0.05	99.39	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					<0.05
	Side	Right	13	2.05 mm (1.56-2.53)	<0.05	98.99	<0.05
		Left	13	1.97 mm (1.50-2.45)	<0.05	98.97	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
	Sex	Male	11	2.13 mm (1.54-2.73)	<0.05	99.28	<0.05
		Female	11	1.85 mm (1.35-2.36)	<0.05	99.19	<0.05
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					>0.05
	Continent	Asia	11	2.50 mm (1.79-3.22)	<0.05	99.53	<0.05
		Europe	5	1.85 mm (1.24-2.46)	<0.05	99.25	<0.05
		South America	3	2.11 mm (1.02-3.21)	<0.05	98.80	<0.05
		North America	1	1.46 mm (1.36-1.55)	<0.05	-	-
		Africa	-	-	-	-	-
		Australia	-	-	-	-	-
		Between-subgroup difference: *P*-value by Q-test for heterogeneity					<0.05

Table 4. Continued

Subgroup		No. of studies	Point estimate (95% confidence interval)	*P*-value	I^2 (%)	Heterogeneity *P*-value
Voxel size	<0.3 mm	7	2.38 mm (1.84-2.93)	<0.05	98.82	<0.05
	≥0.3 mm	5	1.58 mm (0.88-2.27)	<0.05	99.40	<0.05
	Between-subgroup difference: P-value by Q-test for heterogeneity					>0.05
Field of view	Small	4	2.75 mm (2.18-3.32)	<0.05	94.20	<0.05
	Medium	2	2.02 mm (-0.19-4.23)	>0.05	99.46	<0.05
	Large	6	2.08 mm (1.24-2.92)	<0.05	99.78	<0.05
	Between-subgroup difference: P-value by Q-test for heterogeneity					>0.05

dibles (side based). In most studies, it was clear how the prevalence was reported; however, in some studies, both ways could be implied. These exceptions are discussed in detail in the meta-analysis part of the Results section.

Overall, the highest and the lowest patient-based prevalence rates of AL were reported by Haghanifar et al.[12] (95.2%) and de Brito et al.[11] (7.7%), respectively. The highest side-based prevalence was 93.5% , reported by Yang et al.,[22] and the lowest was 6.5%, reported by Sinha et al.[23] The age range of participants was 4 to 98 years. AL lengths ranged from 0.25 mm[13] to 19 mm.[11]

Thirteen studies used a small FOV,[12,24-35] 15 studies used a medium FOV,[14,23,26,36-47] and 16 studies used a large FOV.[1,11,21,22,44-46,48-56] Moreover, 30 studies used a voxel size of less than 0.3 mm,[11-14,22,24,25,28-31,33-35,39-42,44,45,47,49-51,55,57-61] whereas 26 studies used voxels that were 0.3 mm or larger.[1,10,14,21,23,26-28,36,37,40-42,45-47,50-54,58,62-65]

Risk of bias assessment

The risk of bias assessment was conducted using the Joanna Briggs Institute checklist designed for prevalence studies. The ninth question ("Was the response rate adequate, and if not, was the low response rate managed appropriately?") was considered irrelevant for the current research, because the studies evaluated CBCT images and there was no need for participants to answer a questionnaire; therefore, we omitted this question. The overall risk of bias summary is also shown in Figure 2. Two studies[66,67] were considered to have a high risk of bias, 54 had a moderate risk of bias, and 7 had a low risk of bias.[13,23,24,26,34,36,60] As shown in Figure 2, the sample size calculation and randomization processes were the primary origins of bias. The first, fifth, and eighth questions had low risks, and there were some concerns regarding the fourth, sixth, and seventh questions.

Meta-analysis results

The summary results of the analyses conducted in this study are presented in Table 4. AL was detected in 40.6% (95% CI: 32.8%-48.9%, $P<0.05$) of the total population. Forty-one studies were meta-analyzed, and a high level of between-study heterogeneity was observed ($I^2=97.6\%$, $P<0.05$). The subgroup analysis results based on sex and continent are available in Table 4.

Thirty-six percent (95% CI: 27.5%-45.5%, $P<0.05$) of all sides had ALs. Forty-three articles were included in the meta-analysis, and the heterogeneity between the studies was high ($I^2=99.1\%$, $P<0.05$). Regarding the subgroup meta-analysis based on sides, some studies reported the prevalence of AL on the left side, right side, and bilaterally; however, some did not report these items separately and mixed bilateral ALs with those on the right and left. Therefore, a subgroup analysis was conducted only for the right and the left sides. If a study reported bilateral ALs, they were merged into the categories of the right and left and included in the meta-analysis.

As presented in Table 3, 20 studies were included in the AL length meta-analysis. The total mean extension of the AL was 2.23 mm (95% CI, 1.83-2.62 mm, $P<0.05$). A subgroup analysis based on the CBCT-reconstruction image type revealed that the length was 1.92 mm (95% CI, 1.33-2.51 mm, $P<0.05$) in cross-sectional images, 2.90 mm (95% CI, 2.38-3.42 mm, $P<0.05$) in CBCT-reconstruction panoramic images, and 2.23 mm (95% CI, 1.70-2.77 mm, $P<0.05$) in other planes. Tangential, axial, and lateral oblique views were included in the "other planes" subgroup. The difference between subgroups was statistically significant ($P<0.05$), and the heterogeneity for each subgroup was high.

As seen in Table 4, significant differences were found in the prevalence and length ($P<0.05$) of ALs in individuals from different continents, as well as the measured length of ALs on different CBCT-reconstruction images ($P < 0.05$). However, there were no significant differences among other analyzed subgroups.

Discussion

Perhaps the most significant impact of CBCT has been on presurgical assessment and treatment planning in dental implant fixture placement using conventional, digitally planned, or guided surgery, which necessitates a correct depiction of vital structures such as the mandibular canal, its mental foramen, and the sinus floor in the maxilla.[68] Therefore, a precise preoperative evaluation of the mental nerve loop trajectory, incidence, and extension is essential.[1] An inaccurate inspection of the surgical site could increase the risk of inadvertent damage to the anterior loop segment. Almost 37% of patients undergoing implant placement surgery in the mandibular premolar region experienced noticeable changes for up to 2 weeks; symptoms persisted in 10%-15% of these cases.[1,69] The present systematic review and meta-analysis summarized the available data on the prevalence and length of the AL of the mental nerve based on CBCT images through a comprehensive search and critical appraisal of existing evidence.

To the best of the authors' knowledge, 1 systematic review and meta-analysis of the characteristics of AL of the mental foramen has been previously published by Mishra et al.[15] In the current study, more major databases were covered, including Embase, Web of Science, Scopus, and ProQuest, resulting in 31 additional articles (a total of 63 articles), 13,743 participants and 27,075 sides. Moreover, data relevant to imaging protocols (voxel size and field of view) was gathered to help researchers reproduce and improve future studies to examine AL and other anatomic landmarks. Furthermore, 12 subgroup analyses were performed to reveal possible differences between different subgroups and the impacts of population-based characteristics and imaging settings on prevalence and extension of AL, which may be considered in clinical applications.

According to the results, AL was seen in 40.6% of the population, including 34.9% of males and 34.5% of females. The prevalence of AL was 36.0% on both sides, 32.3% on the right side, and 29.7% on the left side. The average extension of AL was 2.39 mm in the total population, 2.13 mm in males, 1.85 mm in females, 2.05 mm on the right side, and 1.97 mm on the left side. No significant difference was found according to sex, side, voxel size, and field of view in terms of prevalence or length.

The studies included in the present review originated from 6 continents. Most studies (36) were conducted in Asia, followed by Europe (11), South America (11), North America (4), Africa, and Australia (1 study each). Interestingly, the analyses' results showed that these 6 continents were significantly different in terms of AL prevalence and length ($P < 0.05$). Geographically, the longest ALs were seen in Asia (2.50 mm), followed by South America (2.11 mm), Europe (1.85 mm), and North America (1.46 mm). However, due to the high level of between-study heterogeneity, these data should be used conservatively in clinical practice. No study evaluated the extension of ALs in Africa and Australia. A statistically significant difference in prevalence was found between South America and North America ($P < 0.05$), with a higher prevalence of AL in South America (22.4%) than in North America (16.8%). However, the prevalence of AL was not significantly different between other continents.

Most of the series of images used to evaluate the mean AL length in the present study were cross-sections or reformatted panoramic images, with a smaller group of compromised tangential planes, oblique axial planes, and 3-dimensional reconstructions. Significant differences were found between the groups ($P < 0.05$). The mean AL length in cross-sectional images was 1.92 mm, while it was 2.90 mm in reformatted panoramic images; these results showed a 1-mm difference between the 2 image types. However, most clinicians believe that CBCT images are reliable and free from distortion and are unaware of the possibility of imprecisions or inconsistencies when taking linear measurements or assessing anatomical landmarks before implant insertion.[70] A systematic review by Fokas et al. assessed the precision of linear measurements on CBCT images and reported that a range of absolute error exceeding a threshold of 1 mm could have clinical implications. Moreover, they suggested that the sub-millimeter accuracy of CBCT may be insufficient in some cases of implant surgery, potentially resulting in clinical complications.[70] In contrast, some studies have recommended a 2-mm safety zone for measurements on panoramic radiography.[3,11] The results obtained by Fokas et al.[70] were consistent with the current results, which showed a 1 mm difference between 3 CBCT-reconstruction image types. Therefore, to interpret the results cautiously, it is suggested that clinicians should consider a 2-mm safety margin from crucial anatomical structures observed on CBCT.

The studies included in this review that used a voxel size of less than 0.3 mm did not show significant differences in the prevalence and mean length of the AL compared to those that used voxel sizes of at least 0.3 mm. Voxel sizes ranged from 0.07 mm to 0.4 mm among 46 studies which reported this parameter. Smaller voxel sizes have diagnostic accuracy in other applications, such as endodontics and the detection of various periodontal defects;[71,72] however, for prevalence and mean length of AL, a voxel size of 0.3-0.4 mm seems to be sufficiently precise.

The findings of this study align with those of other studies reporting no significant differences between voxel sizes (0.2, 0.3, and 0.4 mm) when evaluating linear bone measurements or implant placement.[73-75] No significant differences were found in the prevalence or mean length of ALs depending on the type of field of view (large: >15 cm; medium: 10-15 cm; small: ≤ 10 cm). This indicates that radiation dose reduction settings, such as a limitation of the field of view, may be applied with minimal effects on the accuracy of measurements and the diagnostic outcome.[76]

The overall risk of bias was moderate in the current study. The included studies contained 2 high-risk,[66,67] 7 low-risk,[13,23,24,26,34,36,60] and 54 moderate-risk studies. According to the Joanna Briggs Institute risk of bias assessment checklist, the most biased aspect was the randomization process. This can be ignored because the included studies used CBCT images as samples, and no systematic error could jeopardize the results. Another field of bias in the included studies was related to the method used to determine sample size, which generally seemed more arbitrary than determined through statistical calculations and power analyses. This could affect the external validity of the obtained results. The sample size of the studies ranged from 20 participants in the study of Lee et al.[54] to 1010 in that by Ritter et al.[41]

Furthermore, some studies did not describe their study settings and standard measurement methods of the outcomes in detail, which could jeopardize the reproducibility and reliability of their results. For example, some articles did not report settings such as the CBCT device manufacturer, software, voxel size, or field of view. It is recommended that researchers conduct future studies in adherence to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement[77] to provide a more standardized and reliable report of results.

Overall, it seems the voxel size and field of view of CBCT devices are adequate for accurately identifying the AL; however, due to potential variations between individuals, an overall 2-mm safety margin from such crucial anatomical structures is suggested to be considered when using CBCT images. The overall heterogeneity between the studies of all evaluated subgroups was high, so the results should be used in clinical practice with caution. Moreover, the aspect of the included studies with the greatest concern for bias was the sample size calculation process, which should be considered in designing future studies.

Conflicts of Interest: None

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