RESEARCH ARTICLE
Araştırma Makalesi

Correspondence address
Yazışma adresi
Hüseyin KARAYILMAZ
Department of Pedodontics,
Faculty of Dentistry,
Akdeniz University,
Antalya, Türkiye

dthkarayilmaz@yahoo.com

Received / *Geliş Tarihi* : June 11, 2026
Accepted / *Kabul Tarihi* : June 24, 2026

Cite this article as
Bu makalede yapılacak atıf
Gurbanov E, Karayilmaz H.
Evaluation of Leeway Space in Children and Adolescents Living in the Western Mediterranean Region of Türkiye

Akd Dent J 2026;5(2): 118-127

Elmir GURBANOV
Department of Pedodontics,
Faculty of Dentistry,
Akdeniz University,
Antalya, Türkiye

Hüseyin KARAYILMAZ
Department of Pedodontics,
Faculty of Dentistry,
Akdeniz University,
Antalya, Türkiye

e-ISSN: 2980-0013

Evaluation of Leeway Space in Children and Adolescents Living in the Western Mediterranean Region of Türkiye

Batı Akdeniz Bölgesi Çocuk ve Adolesanlarda Leeway Yer Rezervinin Araştırılması

ABSTRACT

Objectives

This study aimed to determine the amount of Leeway space (LWS) in children and adolescents in the mixed dentition period living in the Western Mediterranean Region, to compare these values between the maxilla and mandible and between the right and left quadrants, and to contribute to the establishment of region-specific reference data.

Material and Methods

This study was conducted by screening the archives of the Departments of Pediatric Dentistry and Orthodontics, Faculty of Dentistry, Akdeniz University. A total of 927 patients aged 6-10 years, in the mixed dentition period and with suitable orthodontic models and orthopantomographic radiographs, were included. Of these patients, 486 were male and 441 were female. The mesiodistal crown widths of primary canines and molars were measured on orthodontic models using a digital calliper, whereas those of unerupted permanent canines and premolars were calculated from orthopantomographic radiographs, and the difference was evaluated.

Results

In all quadrants, the total mesiodistal width of primary canines and molars was greater than that of permanent canines and premolars. In the maxilla, LWS was 0.60583 mm in the right quadrant and 0.60777 mm in the left quadrant. In the mandible, LWS was 1.68058 mm in the right quadrant and 1.67379 mm in the left quadrant. Right and left quadrant values were similar, whereas LWS was more pronounced in the mandible than in the maxilla. In general, tooth dimensions obtained from girls, and therefore LWS, were statistically significantly lower than those obtained from boys.

Conclusion

LWS was determined in children and adolescents in the Western Mediterranean Region of Turkiye, and comparison with accessible literature clearly demonstrated regional differences. Considering these differences, careful evaluation of arch length changes during the mixed dentition period and accurate analysis of LWS are clinically important for the early prediction of future orthodontic problems.

Key Words

Leeway Space, Pediatric Dentistry, Preventive Orthodontics

© Akdeniz University Faculty of Dentistry
DOI: 10.62268/add.1969294
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International Licence.

ÖZ

Amaç

Bu çalışmanın amacı, Batı Akdeniz Bölgesi'nde yaşayan karışık dişlenme dönemindeki çocuk ve adolesan bireylerde Leeway yer rezervi (LYR) miktarını belirlemek, bu değerleri alt ve üst çene ile sağ ve sol kadranlar açısından karşılaştırmak ve bölgeye özgü referans verilerin oluşturulmasına katkı sağlamaktır.

Gereç ve Yöntemler

Çalışmaya, Akdeniz Üniversitesi Diş Hekimliği Fakültesi Pedodonti ve Ortodonti Anabilim Dallarına ait arşivler taranarak, 6-10 yaş aralığında, karışık dişlenme döneminde bulunan, ortodontik modeli ve ortopantomografik radyografisi uygun olan, toplam 927 hasta dahil edilmiştir. Olguların 486'sı erkek, 441'i kızdır. Süt kanin ve süt molar dişlerin mezyodistal kuron genişlikleri ortodontik modeller üzerinde dijital kumpas ile ölçülmüş; henüz sürmemiş daimi kanin ve premolar dişlerin mezyodistal genişlikleri ise ortopantomografik radyografiler üzerinden hesaplanmış ve arasındaki fark değerlendirilmiştir.

Bulgular

Tüm kadranlarda süt kanin ve molar dişlerin toplam mezyodistal genişliği, daimi kanin ve premolar dişlerin toplam mezyodistal genişliğinden daha yüksek bulunmuştur. Üst çene sağ kadranda LYR 0,60583 mm, üst çene sol kadranda 0,60777 mm olarak saptanmıştır. Alt çene sağ kadranda bu değer 1,68058 mm, alt çene sol kadranda ise 1,67379 mm olarak bulunmuştur. Sağ ve sol kadranlar arasında benzer değerler elde edilirken, alt çenede saptanan LYR'nin üst çeneye göre daha belirgin olduğu görülmüştür. Genel olarak kızlardan elden edilen diş boyutlarının ve dolayısıyla LYR'nin erkeklere göre istatistiksel olarak anlamlı derecede daha az olduğu tespit edilmiştir.

Sonuç

Çalışmamız sonucunda Batı Akdeniz Bölgesi çocuk ve adölesanlarda LYR belirlenmiş olup konu ile ilgili erişilebilir kaynaklardan elde edilen literatür sonuçları ile sonuçlarımız karşılaştırıldığında bölgesel farklılıkların olduğu açıkça ortaya konmuştur. Bölgesel farklılıklar göz önünde bulundurularak karışık dişlenme döneminde ark uzunluğu değişimlerinin dikkatle değerlendirilmesi ve LYR'nin doğru analiz edilmesi, ileride oluşabilecek ortodontik problemlerin erken dönemde öngörülmesi açısından büyük klinik önem taşımaktadır

Anahtar Sözcükler

Leeway Yer Rezervi, Çocuk Diş Hekimliği, Koruyucu Ortodonti

INTRODUCTION

Interdental contact relationships (occlusion) represent not only a static occlusal pattern but also a dynamic system associated with masticatory function, speech, and temporomandibular joint movements (1-3). The development of occlusion is shaped by the complex interaction among tooth eruption sequence, jaw growth, the neuromuscular system, and environmental factors. Childhood and adolescence include critical growth periods during which occlusal relationships change rapidly and undergo reorganization (1,2). The mixed dentition period is an important transitional phase in which primary teeth begin to be replaced by permanent teeth and arch length balance is reshaped (4). Tooth-size discrepancies and eruption patterns occurring during this period may form the basis for occlusal disorders that may develop later (5,6).

The mesiodistal size difference between primary and permanent teeth is one of the most important factors affecting arch length balance (7). This difference is defined in the literature as Leeway space (LWS) and contributes to the eruption of permanent teeth in an appropriate position during the mixed dentition period (7). LWS refers to the difference between the total width of the primary canine and molar teeth and the total width of the permanent canine and premolar teeth that replace them (7).

LWS has been reported to be more pronounced in the mandible, allowing mandibular molars to move physiologically in the mesial direction (5,6). This physiological mesialization is considered an important adaptive mechanism contributing to the development of normal Class I molar occlusal relationships (8).

The literature indicates that the amount of LWS may vary according to sex, jaw structure, and population characteristics (5,6). Therefore, determining regional reference values for LWS in individuals living in different geographical regions is important for clinical practice (5,6).

This study aimed to determine the amount of LWS in children and adolescents living in the Western Mediterranean Region and to compare these values between the maxilla and mandible. In addition, the distribution of LWS values according to sex was evaluated.

MATERIAL AND METHODS

The patient archives of the Departments of Pedodontics and Orthodontics at the Faculty of Dentistry, Akdeniz University, were reviewed. Patients aged 6-10 years with orthodontic models and orthopantomographic radiographs obtained on the same day were selected according to the inclusion and exclusion criteria listed below.

Inclusion Criteria

- Born from Turkish parents and raised in the Western Mediterranean Region of Türkiye
- Presence of Class I occlusion in the molar region
- Being in the mixed dentition period
- Presence of primary canine and primary molar teeth on the model
- Permanent canine and premolar teeth have not yet erupted.
- Orthodontic models and orthopantomographic radiographs are suitable for measurement.

Exclusion Criteria

- Presence of congenital craniofacial anomalies
- Presence of skeletal malocclusion
- Early loss of primary canine and molar teeth
- Presence of extensive restorations, excessive wear, or dental anomalies that could affect measurement accuracy
- History of systemic disease

Orthodontic Model Measurements: Orthodontic plaster models were evaluated by the same researcher under standard measurement conditions and adequate lighting. The mesiodistal crown widths of the primary canine and primary molar teeth were measured using a digital measuring instrument with 0.01 mm precision (Oleander Electronic Carbon Fiber Composites Digital Vernier Caliper) (Fig. 1).

Radiographic Measurements: Orthopantomographic radiographs obtained from each patient's archive were used to determine the mesiodistal widths of unerupted permanent canine and premolar teeth. Care was taken to ensure that all orthopantomographic radiographs were obtained under standard conditions using the same device (J. Morita Veraview X800, Kyoto, Japan). For this purpose, the mesiodistal widths of unerupted permanent canine and premolar teeth were measured on the selected orthopantomographic radiographs using the standard imaging and processing software of the radiographic device. (Fig. 1).

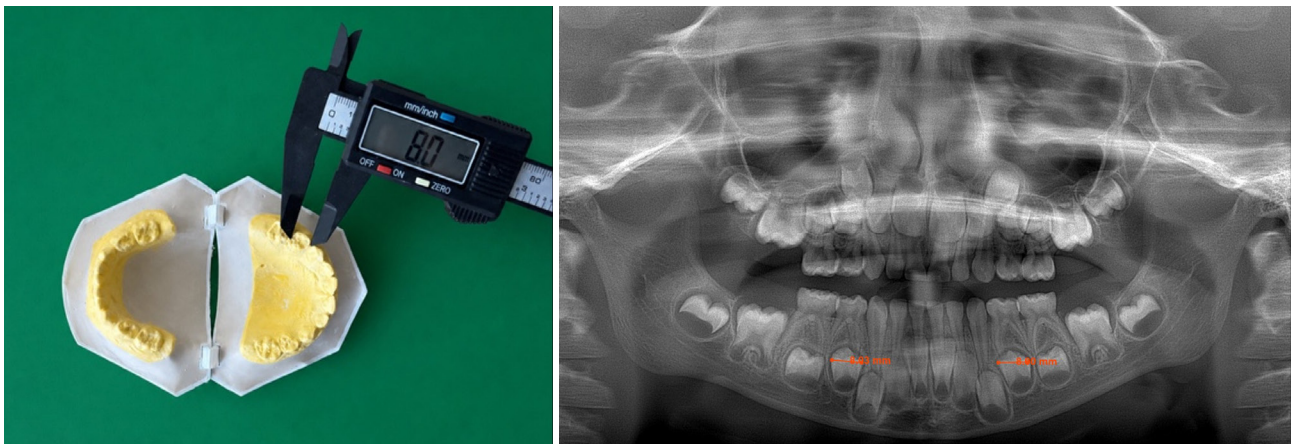

Figure 1. Measurement of mesiodistal crown widths of teeth using plaster models and orthopantomographic radiographs.

The following calculation method was used to eliminate magnification error in the mesiodistal widths of the permanent canine and premolar teeth measured on orthopantomographic radiographs and to determine the actual tooth widths.

$$\frac{\text{unerupted permanent tooth width}}{\text{unerupted permanent tooth width (orthopantomographic radiographs)}} = \frac{\text{erupted deciduous tooth width}}{\text{erupted deciduous tooth width (orthopantomographic radiographs)}}$$

Calculation of LWS: LWS was calcula- ted as the difference between the total mesiodistal crown width of the primary canine and primary molar teeth and the estimated total mesiodistal width of the permanent canine and premolar teeth that replace them.

Calculation of the Sample Group: The sample size of the study was calculated using the results reported in the doctoral thesis of Baharoglu SE (9). The GPOWER 3.1.9.4 program was used to determine the adequate sample size. The power analysis indicated that a total sample size of at least 876 was required with an effect size of 0.19802, an alpha level of 0.05, and a power of 0.90. Accordingly, 950 patient records were identified for the study, considering that some patients might be excluded during model and radiographic measurements for various reasons, such as defects in orthodontic models that could affect measurement values or errors in orthopantomographic radiographic images that prevented standard measurement.

Reliability of the Researcher's Ability to Repeat the Same Measurement: To ensure standardization, all oral examinations and evaluations of the patients in the study and control groups were performed by a single researcher (EG). During the study, after completion of the orthodontic model measurements and radiographic measurements, 30 patients were randomly selected from among those for whom *leeway space* had been calculated. All measurements and calculations for these selected patients were repeated by the same researcher. Differences between repeated measurements and calculations were evaluated using the intraclass correlation coefficient (ICC), and the correlation coefficient was calculated as 0.961.

Statistical Analysis of the Data: The obtained data were entered into the SPSS software package (SPSS 18.00 for Windows, Chicago, IL, USA), and descriptive statistics (minimum, maximum, mean, standard deviation, etc.), reliability analysis *(ICC)*, correlation analysis, and comparison tests were performed. For comparison of quantitative data, Student's t-test was used when parametric assumptions were met (Levene's test), one-way analysis of variance was used for repeated measurements of the groups, and Tukey's HSD multiple comparison test was used for subgroup comparisons. When parametric assumptions were not met, Kruskal-Wallis, Mann-Whitney U, Wilcoxon, and chi-square ($\chi 2$) tests were used for the analysis of qualitative data and group comparisons.

RESULTS

The patient archives of the Department of Pedodontics and the Department of Orthodontics, Faculty of Dentistry, Akdeniz University were reviewed, and 950 patients aged 6-10 years who had orthodontic models and orthopantomographic radiographs were identified after evaluation according to the inclusion and exclusion criteria. However, 23 patient records were excluded from the study because of defects in orthodontic models that could affect measurement values, errors in orthopantomographic radiographic images that prevented standard measurement, and similar reasons. The study was conducted using archive records of 927 patients. Of these 927 patients, whose ages ranged from 72 to 120 months, 486 (52.4%) were male and 441 (47.6%) were female; the mean age was 101.72 ± 21.92 months.

As shown in Table 1, the mesiodistal widths of primary canine teeth were smaller than those of permanent canine teeth in all quadrants. In contrast, the mesiodistal widths of primary first molars were greater than those of permanent first premolars, and the mesiodistal widths of primary second molars were greater than those of permanent second premolars in all quadrants. These differences were highly statistically significant ($P < 0.001$ for all teeth).

When the total mesiodistal widths of the primary canine, first molar, and second molar teeth were compared with the total mesiodistal widths of the permanent canine, first premolar, and second premolar teeth in each quadrant, the mesiodistal widths of the primary teeth were found to be significantly greater than those of the permanent teeth (Tab. 1) ($P < 0.001$).

Table 1. Comparison of the mesiodistal widths of primary and permanent teeth in the upper and lower jaws.

	Teeth	N	Primary Canine/ Molar Teeth Mean±SD	Permanent Canine/ Premolar Teeth Mean±SD	P
Right Upper Jaw	Primary Canine-Perm. Canine	927	6,4544±0,3635	7,2825±0,3827	0,001
	Primary 1st Molar-Perm. 1st Premolar	927	6,8243±0,4228	6,3078±0,2673	0,001
	Primary 2nd Molar-Perm. 2nd Premolar	927	8,8874±0,5286	7,9612±0,5549	0,001
	Total Primary Teeth-Total Permanent Teeth	927	22,1689±0,8564	21,5631±0,7626	0,001
	Leeway Space		0,60583 mm		
Left Upper Jaw	Primary Canine-Perm. Canine	927	6,4534±0,3633	7,2874±0,3774	0,001
	Primary 1st Molar-Perm. 1st Premolar	927	6,8243±0,4228	6,3019±0,2788	0,001
	Primary 2nd Molar-Perm. 2nd Premolar	927	8,8641±0,5941	7,9699±0,5428	0,001
	Total Primary Teeth-Total Permanent Teeth	927	22,1602±0,9167	21,5524±0,7544	0,001
	Leeway Space		0,60777 mm		
Right Lower Jaw	Primary Canine-Perm. Canine	927	5,7660±0,2815	6,2864±0,3514	0,001
	Primary 1st Molar-Perm. 1st Premolar	927	7,3534±0,3360	6,3883±0,3011	0,001
	Primary 2nd Molar-Perm. 2nd Premolar	927	9,5272±0,4320	8,3010±0,4794	0,001
	Total Primary Teeth-Total Permanent Teeth	927	22,6466±0,7289	20,9660±0,8079	0,001
	Leeway Space		1,68058 mm		
Left Lower Jaw	Primary Canine-Perm. Canine	927	5,7660±0,2815	6,2777±0,3323	0,001
	Primary 1st Molar-Perm. 1st Premolar	927	7,3534±0,3360	6,3913±0,3112	0,001
	Primary 2nd Molar-Perm. 2nd Premolar	927	9,5272±0,4320	8,2961±0,4785	0,001
	Total Primary Teeth-Total Permanent Teeth	927	22,6388±0,7250	20,9650±0,7848	0,001
	Leeway Space		1,67379 mm		

As a result of the calculations, LWS was determined as 0.60583 mm in the maxillary right quadrant, 0.60777 mm in the maxillary left quadrant, 1.68058 mm in the mandibular right quadrant, and 1.67379 mm in the mandibular left quadrant.

Total LWS was 1.2136 mm in the maxilla and 3.3544 mm in the mandible. Mandibular LWS was 2.76 times greater than maxillary LWS.

Examination of Figure 2 shows that the total difference values in the maxillary right and left quadrants were very similar, whereas the difference was more pronounced in the mandibular right and left quadrants. This finding indicates that *leeway space* was greater in the mandible.

To demonstrate the distribution between quadrants more clearly, the distribution of LWS in all quadrants is also shown in Figure 3.

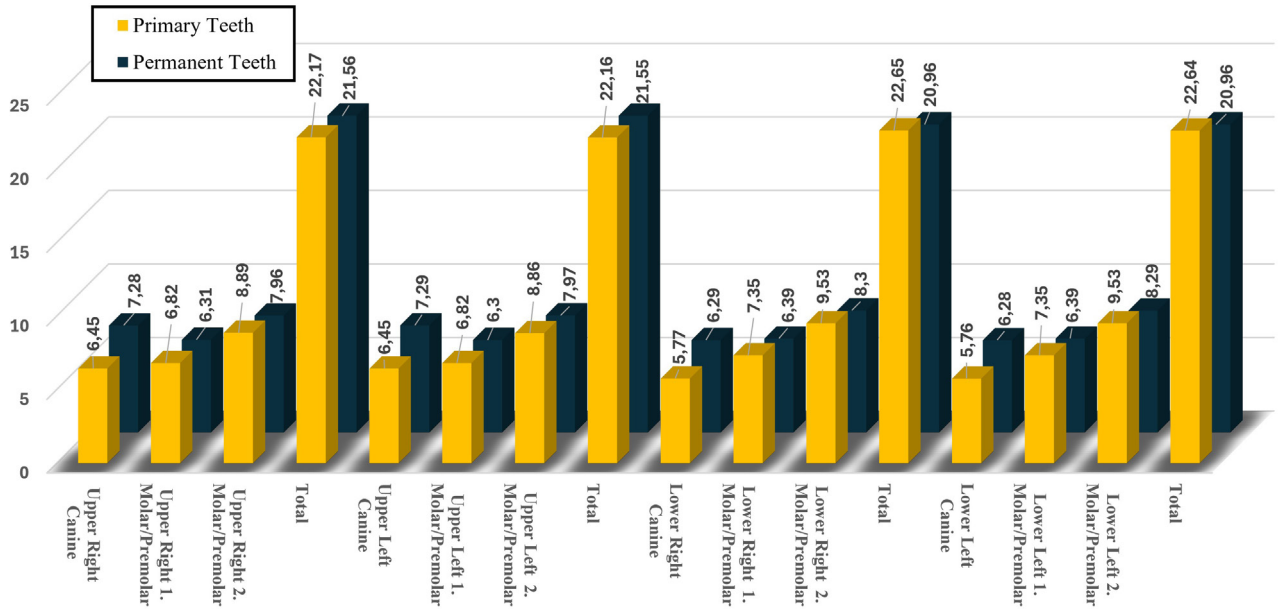

Figure 2. Comparison of mesiodistal widths of primary and permanent teeth according to quadrants of jaws.

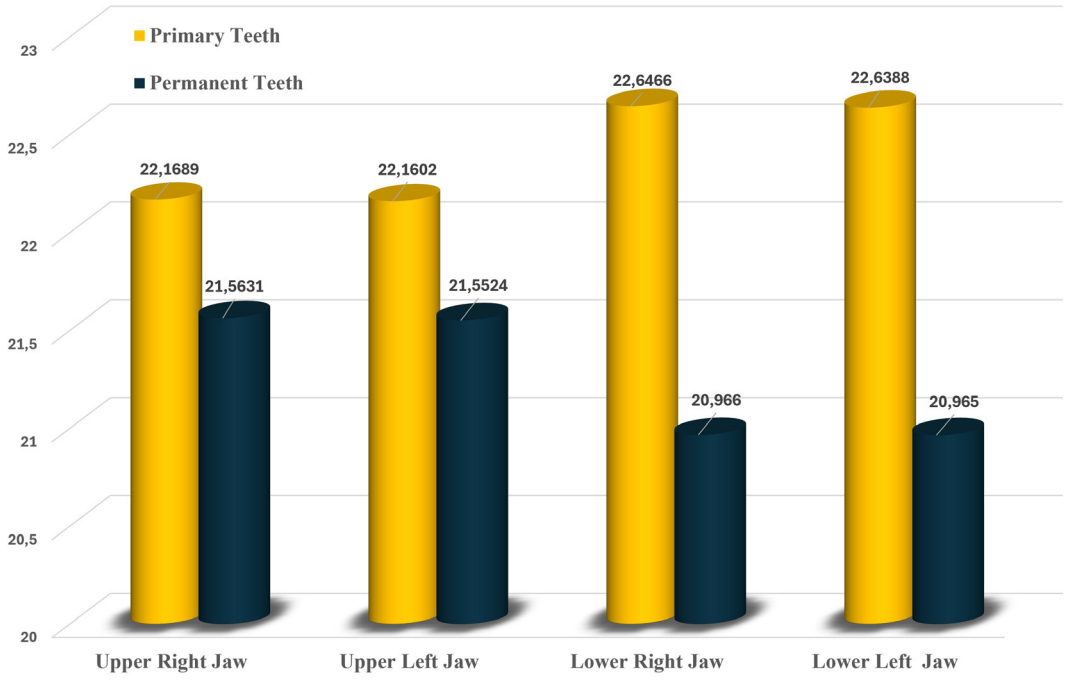

Figure 3. Comparison of total primary-permanent tooth width differences according to quadrants of jaws.

In addition, the effect of sex on the mesiodistal crown dimensions measured from the primary canine, primary first molar, primary second molar, permanent canine, permanent first premolar, and permanent second premolar teeth were investigated and summarized in Table 2. Overall, the mesiodistal dimensions of the primary canine, primary first molar, permanent canine, and permanent first premolar teeth measured in girls were statistically significantly lower than those measured in boys ($P < 0.05$), except for the maxillary left permanent canine. Sex had no statistically significant effect on the mesiodistal dimensions of the primary second molar and permanent second premolar teeth ($P > 0.05$), except for the mandibular left permanent second premolar. The sums of the mesiodistal widths of the primary canine, first molar, and second molar teeth were significantly lower in girls than in boys; similarly, the sums of the mesiodistal widths of the permanent canine, first premolar, and second premolar teeth were also lower in girls than in boys ($P < 0.05$).

Table 2. Comparison of mesiodistal widths of primary and permanent teeth according to gender.

	TEETH	Primary Teeth			Permanent Teeth		
		GIRLS (N=441) Mean±SD	BOYS (N=486) Mean±SD	P	GIRLS (N=441) Mean±SD	BOYS (N=486) Mean±SD	P
Right Upper Jaw	Primary Canine-Perm. Canine	6,26±0,37	6,44±0,34	**0,001**	7,29±0,40	7,47±0,35	**0,001**
	Primary 1st Molar-Perm. 1st Premolar	6,58±0,40	6,85±0,40	**0,001**	6,32±0,21	6,49±0,28	**0,001**
	Primary 2nd Molar-Perm. 2nd Premolar	8,79±0,57	8,78±0,49	0,808	8,07±0,58	8,06±0,54	0,829
	Total Primary Teeth-Total Permanent Teeth	21,64±0,79	22,07±0,86	**0,001**	21,69±0,70	22,02±0,78	**0,001**
Left Upper Jaw	Primary Canine-Perm. Canine	6,26±0,37	6,44±0,33	**0,001**	7,37±0,41	7,41±0,35	0,127
	Primary 1st Molar-Perm. 1st Premolar	6,58±0,40	6,85±0,40	**0,001**	6,34±0,26	6,46±0,28	**0,001**
	Primary 2nd Molar-Perm. 2nd Premolar	8,74±0,69	8,78±0,49	0,308	8,05±0,57	8,09±0,52	0,316
	Total Primary Teeth-Total Permanent Teeth	21,61±0,92	22,08±0,86	**0,001**	21,74±0,68	21,96±0,81	**0,001**
Right Lower Jaw	Primary Canine-Perm. Canine	5,63±0,27	5,70±0,29	**0,001**	6,34±0,29	6,41±0,37	**0,002**
	Primary 1st Molar-Perm. 1st Premolar	7,2±0,31	7,29±0,36	**0,001**	6,46±0,22	6,52±0,37	**0,004**
	Primary 2nd Molar-Perm. 2nd Premolar	9,42±0,39	9,44±0,47	0,462	8,37±0,42	8,42±0,53	0,078
	Total Primary Teeth-Total Permanent Teeth	22,26±0,64	22,41±0,79	**0,001**	21,17±0,59	21,35±0,92	**0,001**
Left Lower Jaw	Primary Canine-Perm. Canine	5,63±0,27	5,70±0,29	**0,001**	6,36±0,32	6,41±0,38	**0,036**
	Primary 1st Molar-Perm. 1st Premolar	7,21±0,31	7,29±0,36	**0,001**	6,46±0,24	6,52±0,35	**0,002**
	Primary 2nd Molar-Perm. 2nd Premolar	9,42±0,39	9,44±0,47	0,462	8,36±0,41	8,44±0,53	**0,007**
	Total Primary Teeth-Total Permanent Teeth	22,26±0,64	22,43±0,80	**0,001**	21,15±0,62	21,37±0,93	**0,001**

DISCUSSION

LWS is defined as the difference between the sum of the mesiodistal crown widths of the primary canine and primary molar teeth and the sum of the mesiodistal crown widths of the permanent canine and premolar teeth that replace them (5,8,10). The concept of LWS was first described in detail by Nance. Nance reported that the grea- ter total width of primary canine and molar teeth compared with the permanent canine and premolar teeth that replace them provides a natural gain in arch space at the end of the mixed dentition period. (8) Subsequent studies have also reported that this natural space gain contributes particularly to the mesial movement of permanent first molars and plays a role in the establishment of normal occlusion (11-15). This difference, which occurs during the mixed dentition period, creates additional space for erupting permanent teeth and plays an important role in the physiological development of occlusion (5,8,12,16-18). Several studies (5,8,15,18,19) have shown that the amount of LWS differs between the mandible and maxilla and is generally greater in the mandible than in the maxilla. This finding is thought to be related particularly to the greater width difference between mandibular primary molars and the premolars that replace them (11, 18, 12, 20). Preservation of the existing natural space reserve during

the mixed dentition period is important for preventing future crowding and for planning eruption guidance appropriately (5, 21, 22).

Therefore, early loss of primary teeth in the supporting zone, changes in arch length, and biological processes related to the eruption direction of permanent teeth should be carefully evaluated from an orthodontic perspective (5,23).

Tooth dimensions are known to be influenced by sex, hereditary characteristics, environmental factors, and ethnic differences; therefore, odontometric data may vary between populations (24-29). For this reason, tooth-size and leeway-space data obtained from different populations may not always be directly applicable to every population. Determining population-specific data is important for more accurate diagnosis and treatment planning (5, 27,30).

Different measurement methods are used in odontometric studies to evaluate the mesiodistal crown widths of primary and permanent teeth (5,7,19,31). In the present study, primary teeth were evaluated on models, whereas permanent teeth were evaluated on panoramic radiographs. Radiographic methods provide an important advantage in determining the dimensions of permanent teeth that have not yet erupted or have not completed eruption during the mixed dentition period, while measuring erupted primary teeth on models allows direct and detailed evaluation. Therefore, the combined use of model and radiographic measurements may be considered an appropriate approach for comparing primary and permanent teeth in the same sample (5,19, 30-36).

The literature shows that reported values for LWS may vary across different populations. Nevertheless, many studies (5,8,15,18,19) have reported that LWS is greater in the mandible than in the maxilla.

In a doctoral thesis study conducted by Baharoglu (9) in 2012 among children in the mixed dentition period in the Central Anatolia Region (Ankara Province), LWS was reported as 1.93 mm on the right and 1.90 mm on the left in the mandible, and 0.79 mm on the right and 0.80 mm on the left in the maxilla. Similarly, in the present study, LWS was greater in the mandible than in the maxilla. However, the maxillary and mandibular values obtained in the present study were slightly lower than the mean values reported by Baharoglu (9). This diffe- rence may be attributable to the different regions in which the studies were conducted.

In the study conducted by Yuen *et al*. (37) in Hong Kong, LWS was reported as 0.3 mm in the maxilla and 2.2 mm in the mandible. In the present study, values of 0.60583 mm and 0.60777 mm were obtained in the maxil- lary right and left quadrants, respectively, and values of 1.68058 mm and 1.67379 mm were obtained in the mandibular right and left quadrants, respectively. Although both studies showed greater LWS in the mandible, the numerical values differed.

In the study conducted by Pradhan *et al*. (38) in children in Nepal, the mean LWS was reported as 0.86 mm in the maxilla and 2.45 mm in the mandible. Although the maxillary and mandibular values in the present study were lower than those reported in that study, both studies showed greater LWS in the mandible than in the maxilla.

In the study conducted by Sun *et al*. (39) in children living in Taiwan, mandibular LWS was reported to be 1.29 mm on each side of the mandibular arch. In the pre- sent study, values of 1.68058 mm and 1.67379 mm were obtained in the mandibular right and left quadrants, respectively, and these values were slightly higher than the mean value reported by Sun *et al*.

In the study conducted by Imai *et al*. (40) on models of the same Japanese individuals at different growth periods, LWS was reported as 1.46 mm in the maxilla and 2.66 mm in the mandible. Although the maxillary and mandi- bular values obtained in the present study were lower than those reported in that study, both studies found greater leeway space in the mandible than in the maxilla.

In the study conducted by Botero *et al*. (41) in school-aged children in Colombia, LWS was reported as 3.622 mm in the mandible and 1.556 mm in the maxilla. Similarly, the present study found greater LWS in the mandible than in the maxilla; however, the maxillary and mandibular values obtained were lower than the mean values reported by Botero *et al*. (59)

In the study conducted by Allen *et al*. (42) on white individuals in the United States, mandibular LWS was evaluated in 2 different birth cohorts and was reported as 2.45 mm per quadrant in individuals born in the 1930s and 2.03 mm in individuals born in the 1990s.

The researchers suggested that mandibular LWS may show a secular decreasing trend. In the present study, values of 1.68058 mm and 1.67379 mm were obtained in the mandibular right and left quadrants, respectively, and these values were lower than the mean value reported by Allen *et al*. (42) in the earlier cohort.

In addition, classical literature has reported mandibular LWS to range between 2.3 and 3.4 mm, whereas maxillary LWS may range between 1 and 1.8 mm (8,15,18,19). Although the values obtained in the present study were below these ranges, they are consistent with the general trend indicating that LWS is greater in the mandible than in the maxilla. This difference may be related to sample characteristics, age distribution, measurement method, and odontometric variability between populations (8,15,18,19).

A similar trend was also observed in tooth-based evaluations. Primary canines were narrower than permanent canines in both the mandible and maxilla, whereas primary molars were wider than permanent premolars; in the mandible, the primary molar-permanent premolar difference was particularly prominent. In the maxillary right quadrant, total primary tooth width was 22.1689 mm and permanent tooth width was 21.5631 mm; in the maxillary left quadrant, these values were 22.1602 mm and 21.5524 mm, respectively. In the mandibular right quadrant, total primary and permanent tooth widths were 22.6466 mm and 20.9660 mm, respectively, and in the mandibular left quadrant, they were 22.6388 mm and 20.9650 mm, respectively. These values support that the total reserve mainly originates from the difference between primary molars and permanent premolars (11,12,18,20).

It is also noteworthy that the total differences (LWS) obtained on the right and left sides in the present study were very similar. The differences of 0.60583 mm on the right and 0.60777 mm on the left in the maxilla, and 1.68058 mm on the right and 1.67379 mm on the left in the mandible, suggest that there was no marked bilateral asymmetry in the maxilla or mandible. In the present study, the total difference in the maxillary right and left quadrants was very similar, and likewise, no remarkable difference was observed between the right and left sides in the mandible. This finding may support the view that the right and left segments show similar biological behaviour when space analysis is performed during the mixed dentition period (5,15,20).

In the present study, the higher total difference values obtained in the mandible than in the maxilla demonstrated that mandibular LWS was more pronounced. This finding is consistent with studies reporting that LWS is greater in the mandible than in the maxilla (5,8,11-15,18-20). The contribution of the difference between primary and permanent canines to the total space reserve appears to be limited, whereas the main effect originates from the posterior segment. This is thought to be related particularly to the greater size difference between mandibular primary molars and the premolars that replace them (11,12,18,20). This result suggests that preservation of the natural space reserve present in the mandibular arch during the mixed dentition period may be particularly important from an orthodontic perspective (5,21,22). This is important for the physiological mesial movement of permanent first molars and the regulation of intra-arch space relationships. In contrast, the markedly greater total difference obtained in the mandibular right and left quadrants compared with the maxilla suggests that leeway space provides a clinically more meaningful space potential, particularly in the mandible (5,8,15,18,19).

In the present study, the total difference values obtained in the maxillary right and left quadrants were very similar; likewise, no marked difference was observed between the right and left sides in the mandible. In contrast, the higher total difference values obtained in the mandible than in the maxilla demonstrated that mandibular LWS was more pronounced. This finding is consistent with previous studies (5,8,15,18,19) reporting that LWS is greater in the mandible than in the maxilla.

Although the total difference obtained in the maxilla was limited, the higher value in the mandible may be explained particularly by the greater width difference between mandibular primary molars and the premolars that replace them. The literature also reports that the primary molar-premolar difference is the main determinant of total LWS, whereas the difference between canines contributes to a lesser extent (11,12,18,20).

The effect of sex on the results of the present study was also evaluated. Overall, tooth dimensions were slightly smaller in girls than in boys, and accordingly, LWS may also be slightly lower in girls. Similarly, in the study conducted by Bishara *et al*. (15) in Iowa, United States, and published in 1988, the difference between maxillary and mandibular LWS was reported as 1.3 mm in males and 1.1 mm in females. Therefore, sex-related differences should be considered in eruption guidance and orthodontic treatment planning.

Overall, the findings of the present study appear to be consistent with the literature results identified through the review of accessible sources; however, the numerical values obtained may differ from the mean values reported in some studies. These differences may be related to sample size, age distribution, sex distribution, measurement method, radiographic evaluation method, and odontometric differences between populations (26-30).

Authors' Contributions
Concept: H.K. Supervision: E.G.; Data Collection and/or Processing: H.K.; Analysis and/or Interpretation: E.G.; Literature Search: E.G.; Writing Manuscript: H.K. Critical Review: H.K.

Funding
The authors declared that this study has received no financial support.

Data Availability
Data is available from the corresponding author upon request.

Ethics Approval
Ethical approval was not required, as this study was not conducted on humans or animals.

Conflicts of Interest
The authors declare that there is no conflict of interest regarding this study.

AI Declaration
No AI tools were used.

Authors' ORCID(s)
Elmir Gurbanov 0009-0005-7006-4135
Hüseyin Karayilmaz 0000-0003-2075-6350

REFERENCES

1. Proffit WR, Fields HW, Larson BE, Sarver DM. Contemporary Orthodontics. 6th ed. Elsevier, Philadelphia, 2019.

2. Proffit WR. On the aetiology of malocclusion. The Northcroft lecture, 1985 presented to the British Society for the Study of Orthodontics, Oxford, April 18, 1985. Br J Orthod. 1986; 13: 1-11.

3. Okeson JP. Management of Temporomandibular Disorders and Occlusion. 7th ed. Mosby, St. Louis, 2012, p. 488.

4. Moorrees CFA, Reed RB. Biometrics of crowding and spacing of the teeth in the mandible. Am J Phys Anthropol. 1954; 12: 77-88.

5. Bishara SE, ed. Textbook of Orthodontics. 1st ed. W.B. Saunders, Philadelphia, 2001, p.592.

6. Bishara SE. Class II malocclusions: diagnostic and clinical considerations with and without treatment. Semin Orthod. 2006; 12: 11-24. doi:10.1053/j.sodo.2005.10.005

7. Moyers RE. Handbook of Orthodontics for the Student and General Practitioner. 3rd ed. Yearbook Medical Publishers, Chicago, 1973, p. 778.

8. Nance HN. The limitations of orthodontic treatment: I. Mixed dentition diagnosis and treatment. Am J Orthod Oral Surg. 1947; 33: 177-223.

9. Baharoğlu SE. Toplumumuzda Karma Dişlenme Dönemindeki Normal Okluzyonlu Çocuklarda Sürekli 1. Molarların Kapanışlarının ve Leeway Yer Rezervlerinin Araştırılması. Doktora tezi, Ankara, Ankara Üniversitesi Sağlık Bilimleri Enstitüsü, Pedodonti Anabilim Dalı; 2012.

10. Ülgen M. Ortodonti: Anomaliler, Sefalometri, Etiyoloji, Büyüme ve Gelişim, Tanı. Ankara: Ankara Üniversitesi Basımevi; 2006.

11. Fisk RO. Normal mandibular arch changes between ages 9-16. J Can Dent Assoc. 1966; 32: 652-8.

12. Steigman S, Harari D, Kuraita-Landman S. Relationship between mesiodistal crown diameter of posterior deciduous and succedaneous teeth in Israeli children. Eur J Orthod. 1982; 4: 219-27. doi: 10.1093/ejo/4.3.219

13. Seipel CM. Variation of Tooth Position: A Metric Study of Variation and Adaptation in the Deciduous and Permanent Dentitions. Lund: Ohlsson, 1946. Svensk Tandläkare-Tidskrift Supplementum 39.

14. Brown T, Margetts B, Townsend GC. Comparison of mesiodistal crown diameters of the deciduous and permanent teeth in Australian Aboriginals. Aust Dent J. 1980; 25: 28-33. doi: 10.1111/j.1834-7819.1980.tb03660.x

15. Bishara SE, Hoppens BJ, Jakobsen JR, *et al*. Changes in the molar relationship between the deciduous and permanent dentitions: a longitudinal study. Am J Orthod Dentofacial Orthop. 1988; 93: 19-28. doi: 10.1016/0889-5406(88)90189-8

16. Clinch L. Symposium on aspects of the dental development of the child. 1. The development of the deciduous and mixed dentitions. Dent Pract Dent Rec. 1966; 17: 135-44.

17. Clinch LM. An analysis of serial models between three and eight years of age. Dent Rec. 1951; 71: 61-72.

18. Nanda RS, Chawla JM. Variability of leeway space. J Indian Dent Assoc. 1973; 45: 99-108.

19. Hixon EH, Oldfather RE. Prediction of lower canine and premolar widths in the mixed dentition. Angle Orthod. 1958; 28: 236-40.

20. Moorrees CFA, Chadha JM. Available space for the incisors during dental development: a growth study based on physiologic age. Angle Orthod. 1965; 35: 12-22.

21. Hotz RP. The role of orthodontics in treatment management of cleft lip and palate. Cleft Palate J. 1970; 7: 371-9.

22. Hoffding J, Kisling E. Premature loss of primary teeth: Part I. Its overall effect on occlusion and space in the permanent dentition. ASDC J Dent Child. 1978; 45: 279-83.

23. Baume LJ. Physiological tooth migration and its significance for the development of occlusion; the biogenesis of accessional dentition. J Dent Res. 1950; 29: 331-7.

24. Altemus LA. Frequency of the incidence of malocclusion in American Negro children aged twelve to sixteen. Angle Orthod. 1959; 29: 189-200.

25. Lavelle CLB. Maxillary and mandibular tooth size in different racial groups and in different occlusal categories. Am J Orthod. 1972; 61: 29-37.

© Akdeniz University Faculty of Dentistry Gurbanov E. and Karayilmaz H.

26. Bailit HL. Dental variation among populations. An anthropologic view. Dent Clin North Am. 1975; 19: 125-39.

27. Bishara SE, Jakobsen JR, Abdallah EM, *et al*. Comparisons of mesiodistal and buccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico, and the United States. Am J Orthod Dentofacial Orthop. 1989; 96: 416-22.

28. Santoro M, Ayoub ME, Pardi VA, *et al*. Mesiodistal crown dimensions and tooth size discrepancy of the permanent dentition of Dominican Americans. Angle Orthod. 2000; 70: 303-7. doi:10.1043/0003-3219(2000)070<0303:MCDATS>2.0.CO;2

29. İşcan MY, Kedici PS. Sexual variation in bucco-lingual dimensions in Turkish dentition. Forensic Sci Int. 2003; 137: 160-4. doi: 10.1016/s0379-0738(03)00349-9

30. Arslan SG, Dildeş N, Kama JD, *et al*. Mixed-dentition analysis in a Turkish population. World J Orthod. 2009; 10: 135-40.

31. Tanaka MM, Johnston LE. The prediction of the size of unerupted canines and premolars in a contemporary orthodontic population. J Am Dent Assoc. 1974; 88: 798-801.

32. Bishara SE, Jakobsen JR. Comparison of two nonradiographic methods of predicting permanent tooth size in the mixed dentition. Am J Orthod Dentofacial Orthop. 1998; 114: 573-6. doi: 10.1016/s0889-5406(98)70019-8

33. Kapoor DN, Chawla TN. A study on mesio-distal crown width of anterior teeth among North Indians. J Indian Dent Assoc. 1973; 45: 241-5.

34. Macko DJ, Ferguson FS, Sonnenberg EM. Mesiodistal crown dimensions of permanent teeth of black Americans. ASDC J Dent Child. 1979; 46: 314-8.

35. Merz ML, Isaacson RJ, Germane N, *et al*. Tooth diameters and arch perimeters in a black and a white population. Am J Orthod Dentofacial Orthop. 1991; 100: 53-8. doi: 10.1016/0889-5406(91)70049-3

36. Bernabé E, Flores-Mir C. Are the lower incisors the best predictors for the unerupted canine and premolar sums? An analysis of a Peruvian sample. Angle Orthod. 2005; 75: 202-7. doi: 10.1043/0003-3219(2005)075<0198:ATLITB>2.0.CO;2

37. Yuen KK, Tang EL. Relations between the mesiodistal crown diameters of the primary and permanent teeth of Hong Kong Chinese. Arch Oral Biol. 1996; 41: 1-7. doi:10.1016/0003-9969(95)00107-7

38. Pradhan M, Dhital S, Joshi U, *et al*. Mean Leeway space in Nepalese children attending a tertiary care hospital, Bhaktapur: a radiographic evaluation. J Kathmandu Med Coll. 2019; 8: 227-30. doi: 10.3126/jkmc.v8i4.32389

39. Sun KT, Wu YZ, Tsai MC, *et al*. Effects of gender and age in mandibular leeway space for Taiwanese children. Children (Basel). 2021; 8: 999. doi: 10.3390/children8110999

40. Imai H, Sakurai A, Shintani S. Reconsideration of Leeway space calculated using models from same patients at different growth stages. Bull Tokyo Dent Coll. 2023; 63: 167-75. doi: 10.2209/tdcpublication.2021-0046

41. Botero P, Gonzalez Ariza S, Meneses D, *et al*. Appraisal of the difference between the mesiodistal diameters of deciduous incisors and molars and permanent teeth. Eur J Paediatr Dent. 2015; 16: 39-44.

42. Allen TR, Trojan TM, Harris EF. Evidence favoring a secular reduction in mandibular leeway space. Angle Orthod. 2017; 87: 576-82. doi: 10.2319/091416-688.1

© Akdeniz University Faculty of Dentistry Gurbanov E. and Karayilmaz H.