The assessment of tooth size and dental arch domensions among young Kosovar population

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DOCTORAL DISSERTATION

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PROCJENA VELIČINE ZUBA I DIMENZIJA ZUBNIH LUKOVA U MLADE KOSOVSKE POPULACIJE

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SUMMARY

THE ASSESSMENT OF TOOTH SIZE AND DENTAL ARCH DIMENSIONS AMONG YOUNG KOSOVAR POPULATION

In the present study, the relationship between tooth sizes, tooth size ratios, and dental arch dimensions in terms of sex and malocclusion classes was investigated. The tooth sizes of the upper and lower teeth in both jaws, excluding the third molars, were measured on dental casts of 400 Kosovar adolescents using mesiodistal width (MD), buccolingual width (BL), crown height, mesiobuccal-distolingual (MBDL) and mesiolingual-distobuccal (MLDB) diagonal widths. Tooth size ratios also were calculated by using measurements of the mesiodistal widths of anterior and posterior maxillary and mandibular teeth. The dental arch dimensions including overjet, overbite, upper and lower incisal irregularity, arch width, arch length, arch perimeter, arch depth, arch form, palatal dimensions, and palatal height index were measured using a digital caliper and 3D orthodontic compass. The data were analyzed using parametric and non-parametric tests to determine the differences between tooth sizes, tooth size discrepancies, and dental arch dimensions regarding sex and malocclusion classes.

Regarding sex, the study's results demonstrated that males had larger tooth size dimensions and lower incisor irregularity (LII) than females. In contrast, no statistically significant sex differences were found in tooth size ratios, overjet, and overbite. In general, male arch dimensions were larger than female, with the exception of the maxillary arch form, which was larger in females.

Regarding the malocclusion classes, the findings of the study also indicate significant differences between malocclusion classes and tooth size dimensions of maxillary and mandibular teeth. On the other hand, the majority of teeth showed no significant differences in buccolingual width (BL) and mesiobuccal-distolingual (MBDL) diagonal crown width measurements. Further, class II malocclusion showed an anterior ratio difference between malocclusion classes. However, the overall and posterior ratios did not differ significantly. Regarding the differences between malocclusion classes and dental arch dimensions, the results indicated significant differences between malocclusion classes in terms of maxillary arch widths, maxillary arch length, maxillary arch perimeter, maxillary arch depth, and palatal length.

Keywords: Tooth size, Tooth size discrepancies, Dental arch dimensions, Kosovar adolescents, Sexual dimorphism

PROŠIRENI SAŽETAK

PROCJENA VELIČINE ZUBA I DIMENZIJA ZUBNIH LUKOVA U MLADE KOSOVSKE POPULACIJE

Razumijevanje varijacija u veličini zuba i dimenzijama zubnog luka među ovom populacijom može pružiti ključne uvide u njihovu orofacijalnu morfologiju i doprinijeti razvoju prilagođenih ortodontskih pristupa. S obzirom na nedostatak studija koje se bave specifičnostima dentalne morfologije kod adolescenata s Kosova, ova studija ima za cilj pružiti temeljne informacije o veličini zuba i dimenzijama zubnog luka u ovoj populaciji.

Cilj istraživanja

Cilj ovog istraživanja je bio odrediti veličine zuba (mezio-distalni (MD), buko-lingvalni (BL), meziobukalno-distolingualni (MBDL) i meziolingualni-distobukalni (MLDB) dijagonalni promjer), procijeniti Littleov indeks nepravilnosti, odrediti prijeklop i pregriz; dimenzije zubnih lukova (prednja i stražnja širina zubnog luka; prednja i stražnja dužina zubnog luka, indeks visine nepca i opseg zubnog luka), kao i prednji, stražnji i ukupni omjer usklađenosti donjih i gornjih zuba ovisno o spolu i vrsti prisutne ortodontske anomalije.

Materijali i metode

Uzorak od 400 školske djece u dobi od 13 do 19 godina nasumično je odabran tehnikom uzorkovanja u više faza u sedam gradova na Kosovu u 14 različitih škola. Ova je dobna skupina odabrana kako bi se smanjio utjecaj uslijed karijesa, restauracija, oštećenja i erozija na dimenzije zuba. Materijal za istraživanje sastojao se od 400 gipsanih odljeva školske djece koji su prikupljeni u sedam privatnih stomatoloških klinika u Republici Kosovo. Kriteriji za uključivanje bili su: kosovska nacionalnost, 13-19 godina starosti; prisutni svi trajni zubi osim trećih trajnih kutnjaka, bez prethodne ili trenutne ortodontske terapije; bez abrazije zuba, bez oštećenja ili velikih restauracija; odsutnost traume i abnormalne morfologije zuba, dobra kvaliteta sadrenog modela. Za podjelu uzorka prema vrsti okluzije korištena je klasifikacija po Angle-u.

Svi ispitanici, odnosno njihovi roditelji ili skrbnici, upoznati su s načinom i svrhom provođenja istraživanja te su potpisali informirani pristanak. Prikupljeni su pojedinačni podaci: dob, spol, datum uzimanja otiska i identifikacijski broj (ID). Nakon uzimanja otisaka ireverzibilnim hidrokoloidnim materijalom (alginatom) u privatnoj stomatološkoj poliklinici, isti su izliveni u sadri i izrađeni studijski modeli. Mjerenja su izvršena izravno na modelu pomoću digitalne pomične mjerke (CD-6'ASAS; Mitutoyo Corp., Kanagawa, Japan), s točnošću od 0,01 mm, i korištenjem trodimenzionalnog ortodontskog šestara po Korkhaus-u (028-350-00; Dentaurum GmbH, Ispringen, Njemačka). Podaci su analizirani pomoću parametarskih i neparametarskih testova za utvrđivanje razlika između veličina zubi, odstupanja u veličinama zubi i dimenzijama zubnog luka s obzirom na spol i vrstu ortodontske anomalije.

Rezultati

Rezultati su pokazali da dječaci imaju veće dimenzije zuba (mezio-distalni (MD), buko-lingvalni (BL), meziobukalno-distolingualni (MBDL), meziolingualni-distobukalni (MLDB) dijagonalni promjer i visina krune) te nepravilnosti sjekutića prema Littleovom indeksu u odnosu na djevojčice. S druge strane, nisu pronađene statistički značajne razlike između spolova u prednjem omjeru i pregrizu.

Nadalje, sve dimenzije zubnog luka bile su statistički značajno različite između skupna po spolu, osim oblika donjeg zubnog luka i indeksa visine nepca. Općenito, dimenzije luka kod muškaraca bile su veće od dimenzija luka kod žena, što ukazuje na prisustvo spolnog dimorfizma u ljudskoj orofacijalnoj morfologiji.

Rezultati su također pokazali značajne razlike u meziodistalnoj širini pojedinih gornjih zuba (12, 13, 14, 22, 23, 24) i donjih zuba (33, 34, 36) između ispitanika s različitim anomalijama. Konkretno, klasa I je imala najviše vrijednosti, a zatim klase II i III (p-vrijednost $<0,005$).

Većina zuba nije pokazala značajne razlike u vrijednostima bukolingvalne širine zuba kod ispitanika s različitim anomalijama. Međutim, primijećene su značajne razlike kod donjih zuba (31, 32, 44) ($p<0,05$), pri čemu su ispitanici s anomalijom klase III imali veće vrijednosti u odnosu na klasu II i I za zube 31, 32, dok su ispitanici s klasom I imali veće vrijednosti u odnosu na klase II i III za zub 44.

Vrijednosti visine krune gornjih i donjih zuba statistički se značajno razlikuju za zube 22, 23, 24, 31, 32, 34, 35, 36, 37, 41, 42, 45 ovisno o prisutnoj dentalnoj klasi na prvim trajnim molarima. Razlike u dijagonalnoj širini pronađene su samo kod zuba 16.

Rezultati usporedbe između klasa malokluzija i dijagonalnog promjera krune MLDB (gornji i donji zubi) pokazali su značajne razlike kod zuba 14, 15, 31, 32, 33, 41, 42 i 43. Konkretno, kod ispitanika s klasom I pronađene su najveće vrijednosti za zube 14, 15, dok su kod klase III najveće vrijednosti izmjerene za zube 31, 32, 33, 41, 42, 43.

Ukupni i stražnji omjer prema Boltonu nisu se značajno razlikovali kod ispitanika s različitim klasama po Angleu. Među kosovskim adolescentima koji su odstupali više od dva standardna odstupanja od Boltonovih prosjeka, omjer veličine prednjih zuba iznosio je 41,37%, a ukupni omjer veličine zuba bio je 23,79%.

Zaključak

Nalazi ove studije otkrili su značajne razlike u veličini zuba i dimenzijama zubnih lukova ovisno o prisutnoj ortodontskoj anomaliji kod adolescenata s Kosova. Kod dječaka su pronađene veće dimenzije zuba i zubnih lukova u usporedbi s djevojčicama, što ukazuje na spolni dimorfizam u orofacijalnoj morfologiji. Ove razlike treba uzeti u obzir prilikom procjene zdravlja zubi i planiranja liječenja.

Studija je pokazala značajne varijacije u širini zuba, visini krune i dijagonalnoj širini krune kod ispitanika s različitim vrstama ortodontskih anomalija. Ispitanici kod kojih je bila prisutna anomalija klase I su općenito pokazali veće vrijednosti širine zuba i visine krune, dok su ispitanici s anomalijom klase III imali veće vrijednosti u dijagonalnoj širini krune. Omjer veličine prednjih zuba značajno se razlikovao kod ispitanika s anomalijom klase II, dok ukupni i stražnji omjeri nisu pokazali značajne razlike između pojedinih vrsta ortodontskih anomalija. Osim toga, 41.37% adolescenata s Kosova (više od dvije standardne devijacije od prosječnih vrijednosti prema Boltonovim normama) pokazuje odstupanja od prosječnih omjera veličine zuba, posebno u prednjem dijelu zubnog luka.

Ovi rezultati prikazuju karakteristike veličine zuba u adolescenata s Kosova, ističući potrebu za razlike ovisne o spolu i vrsti ortodontske anomalije što treba uzeti u obzir prilikom planiranja ortodontskog liječenja. Rezultati također ukazuju na specifičnosti morfologije zuba i ističu važnost studija specifičnih za populaciju u ortodonciji.

Daljnja istraživanja su potrebna kako bi se istražili temeljni faktori koji doprinose opaženim razlikama između spolova, varijacijama specifičnim za ortodontske anomalije i odstupanjima od prosječnih omjera veličine zuba. Razumijevanje tih faktora može dovesti do unaprijeđenih pristupa ortodontskom liječenju prilagođenih specifičnim potrebama adolescenata s Kosova i potencijalno doprinijeti boljim oralnim zdravstvenim ishodima u ovoj populaciji.

Ključne riječi: veličina zuba, razlike u veličini zuba, dimenzije zubnog luka, kosovarski adolescenti, spolni dimorfizam

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List of abbreviations:

APR	*Anterior percentage relation*
BL	*Bucco lingual*
C-C	*Canine to Canine distance*
DB	*Disto buccal*
DL	*Disto lingual*
FDI	*World Dental Federation*
LII	*Lower incisor irregularity*
M_1-M_1	*First molar to the first molar distance*
MB	*Mesio buccal*
MD	*Mesio distal*
ML	*Mesio lingual*
mm	*millimeters*
P_1-P_1	*First premolar to first premolar distance*
P_2-P_2	*Second premolar to second premolar distance*
SD	*Standard deviation*
TSD	*Tooth size discrepancy*
UII	*Upper incisor irregularity*
VAR	*Variance*

1. INTRODUCTION

1.1 Tooth size

Among all the tissues in the human body, teeth are the hardest and most chemically stable tissue, making them an excellent material for various research purposes. Researchers in anthropology, genetics, odontology, and forensic science all use teeth to study living and non-living populations and conduct laboratory research (1). Teeth are valuable in the scientific community due to their durability and stability, which make them an invaluable resource. Scientists use human teeth to track evolutionary changes in a species, identify genetic markers, and observe how environmental hazards affect the body. Teeth are also useful in forensic investigations to identify individuals, giving insights into their past. Due to all these reasons, they play a crucial role in the scientific community due to the valuable insights they offer into the human body's functions.

In the development and functioning of human dentition, as one of the most complex adaptive systems, genetic, epigenetic, and environmental influences all play a role. This complexity gives it anthropological significance, as it can be used to gain insight into human evolution and behavior (2). Human dentition consists of two types: deciduous and permanent dentition. Their function determines all aspects of beauty (aesthetics), chewing (digestion), and speech (phonation) (3).

Moreover, the teeth are arranged in the face and mouth in harmony with each other, including the muscles of mastication, the tongue, and the bones of the upper and lower jaws (4). Besides, according to Kieser (5), the teeth are the only hard tissue in the body that can be directly observed without the need for radiographic or other non-invasive interventions. This makes the teeth a valuable tool for dentists and other health professionals when diagnosing and treating oral health issues.

Modern cast-making techniques have provided anthropologists with accurate, permanent, and easily accessible records of the dentition of a wide range of human populations. Metric data from such collections analyzed with multivariate statistical techniques have contributed significantly to our understanding of human variations (6). Such techniques have been extremely beneficial in understanding the evolution and history of human populations.

Anthropologists can now acquire detailed records of dentition that can be studied and compared to other populations, providing invaluable information on the biological and cultural variations between different populations, as well as their genetic relationships. In summary, modern cast-making techniques have been essential in understanding human variations and the complex history of human populations.

Moreover, the tooth size relationship is an important factor in the diagnosis and planning of orthodontic treatment (6). In order to achieve good occlusion and the best possible esthetic and functional orthodontic treatment results, it is necessary to maintain the appropriate balance between the mesiodistal tooth size of the upper and lower dental arches (7, 8). It is important to recognize the importance of tooth size relationships in orthodontic treatment planning, and to identify discrepancies between the arches to ensure the best possible results.

However, most patients come to an orthodontist with complaints: either crowding, tooth spacing, or both, which are a major aesthetic and functional problems (9). Since crowding and spacing are highly dependent on jaw size and tooth size, the importance of mesiodistal crown width as one of the two factors in the equation is clear (10). As such, it is important for orthodontists to be mindful of this factor when creating treatment plans for their patients.

On the other hand, the relationship between the mesiodistal crown widths of the deciduous and permanent teeth likewise plays an important role in the development of the occlusion of the permanent dentition (11). According to Bolton (12), the mesiodistal tooth size of the maxillar and mandibular dental arch should correspond to the best occlusion, overjet and overbite at the end of orthodontic treatment. However, an intermaxillary tooth size disparity is among the numerous factors that can impair the success of orthodontic treatments.

1.1.1 The mesiodistal dimension of tooth crown

Mesiodistal width has been referred to by a variety of authors using different terms, including mesiodistal width (12), mesiodistal crown diameter (13), and tooth width (14). According to Bishara et al. (15), the mesiodistal width of a tooth is measured by measuring from the anatomical contact of one tooth to the other from the buccal side of the teeth, or the occlusal side in the case of a rotated tooth. While Kieser et al. (16) defined the mesiodistal dimension as the greatest distance between the contact points of a tooth in normal occlusion, Moorrees et al. (10) defined it as the greatest distance between the contact points. Other researchers determined the mesiodistal dimensions by measuring a line between the mesial and distal contact points of each crown when the teeth are in normal occlusion (16, 17).

Interestingly, most researchers claim that the mesiodistal dimension line represents the greatest distance between the contact points or the points where contact occurs (18-20). Lavelle believes that the mesiodistal line, when measured parallel to the occlusal plane, represents the greatest distance between normal contact points in the proximal areas of the tooth crown (18). In spite of this, teeth with significant proximal and occlusal wear are not recommended for odontometric purposes (21). Some authors have stated that measurement of the mesiodistal line becomes more accurate when the calipers are held parallel to the occlusal surface of the teeth and the buccal surface of the teeth (19,20).

Generally, studies on sex determination typically use the mesiodistal and buccolingual measurements of the teeth (21). Additionally, Garn (22) defines sexual dimorphism as the difference between sexes in size, stature, and appearance. This can be applied to identifying people by their mouths because no two mouths are identical. Moreover, differences between sexes and populations in tooth size have been found (23).

Another study by Arya et al. (24) investigated the mesiodistal measurements in both sexes with classes I and II. The sample included 48 males and 47 females of Northwestern European origin between the ages of 4.5 and 14 years. The values were higher in males than females, except for the permanent lower central incisors. When the type of occlusion was disregarded, significant sex differences were found. In the deciduous dentition, there was only a significant sex difference in the upper second molar.

Lavelle (18) reported that boys had larger tooth sizes than girls. This is consistent with Perzigian (25), with the exception of the upper lateral incisors.

Richardson and Malhotra (26) also found that male teeth were larger than female teeth for each tooth type in both dental arches. The study measured the mesiodistal crown dimensions of 3,980 individual teeth, including 81 males and 81 females, in African-Americans. Further, Axelsson and Kirveskari (20) also found sexual dimorphism.

Kieser (16) studied how to use odontometric measurements to determine sex. Using MD measurements, he discovered significant differences between male and female teeth. Genetic and environmental factors are the causes of the differences between the populations. In light of this, Zorba (27) claims that data collection from different populations is crucial for understanding dental sexual dimorphism.

1.1.2 The buccolingual dimension of tooth crown

In the oral cavity, the buccolingual dimension is an important consideration and it can be defined in several ways, including buccolingual crown diameter (13) and buccolingual breadth (16, 28).

Several researchers (11, 16, 19, 20, 28) have indicated that the maximum buccolingual dimension of the tooth should be used as the norm for measurement, perpendicular to its mesiodistal dimension. In other words, this value refers to the maximum distance between the buccal and lingual crown convexities, determined by measuring at right angles to the mesiodistal crown diameter, according to Lavelle (18).

In 2015, in a study of the Pakistani population with class I malocclusion, Shahid et al. (29) defined the buccolingual crown dimension as the largest distance perpendicular to the occlusal plane between the buccal-labial and lingual surfaces. They showed that males had larger dimensions than females. Furthermore, Kieser et al. (16) investigated sex determination using odontometric measurements (mesiodistal and buccolingual crown measurements) in 124 South African Caucasians. Using BL measurements, they found considerable differences between male and female teeth.

In addition, male teeth were also significantly larger in Turks (30) and Aboriginal Australians (31). As a result, the extent of sexual dimorphism appears to differ between populations (32).

1.1.3 The diagonal crown dimension

Diagonal crown dimensions such as the mesiobuccal-distolingual crown width (MBDL) and the mesiolingual-distobuccal crown width (MLDB) are defined as the maximum distance between the mesiobuccal corner and the distolingual corner (MBDL), and the maximum distance between the mesiolingual corner and the distobuccal corner (MLDB) (33, 34).

Researchers in the field of anthropology and dentistry have demonstrated that there is a sex difference in the size of teeth in both the buccolingual and the mesiodistal dimensions (linear dimensions) of teeth (30, 32, 35,36), as well as diagonal dimensions of the teeth (37-39).

In a study of the Pakistan population (2015) with class I malocclusion, Shahid et al. (29) measured the diagonal crown dimensions as MLDB and MBDL of the maxillary and mandibular teeth. They also showed that males had greater dimensions than females.

Using univariate statistics and stepwise discriminant function analyses of diagonal crown diameters, Manchanda et al. (37) found that diagonal crown diameters were greater in males than females for all but one tooth (MLDB of the maxillary lateral incisor). The difference was statistically significant for the MBDL dimensions of the maxillary and mandibular central incisor, canine, and the first and second molars, and the MLDB dimensions of the maxillary and mandibular canine, and the first and second molars. The lateral incisors and premolars did not show significant sexual dimorphism.

A study conducted by Karaman (38), in which diagonal crown measurements (MBDL and MLDB) were examined and their effects on predicting sex in a Turkish population, they found that seven out of 14 measurements in the maxilla were significantly greater in males than they were in females. Further, ten out of 14 measurements in the mandible were significantly greater in males.

By using the diagonal dimensions (MLDB and MBDL) of the molars, in the study that they carried out on the attribution of sex among modern Greeks, Zorba et al. (27) found that male molars were larger than female molars, which is also consistent with the study results of Manchanda et al. (37).

Zorba et al. (27) found in their study that amongst maxillary and mandibular molars crown MLDB dimensions show more sexual dimorphism than crown MBDL dimensions. Manchanda et al. (37) found that the diagonal crown dimensions of both the maxillary and the mandibular second molars showed more dimorphism than the first molars, except for the MLDB dimension of the mandibular molar. On the other hand, Sharma et al. (40) reported that the diagonal crown dimensions (MBDL and MLDB) of both the maxillary first molars, as well as the second molars, exhibited sexual dimorphism, with male dimensions larger than females.

1.1.4 The crown height

In the dental literature, the concept of crown height is discussed in various terms, including "incisogingival height" (12) and "crown height" (13, 41, 42). It is commonly measured at the buccal surface. Bolton (12) described the concept of crown height as the occlusogingival line, which indicates the length of the crown from the occlusal plane to the gingival margin.

Several authors have since used the term "crown height" in their writings (13, 41, 42). While the exact measurement of crown height may vary depending on the practitioner, it is important to note that the height of the crown has an impact on the placement of the dental restoration and the occlusal plane. The amount of tooth structure available above the gum line affects the retention and stability of the restoration. If the crown height is insufficient, there may not be enough tooth structure to support the restoration properly.

For premolars, canines and incisors, Lavelle (13) used this vertical measurement on the labial surface from the most apical curvature of the free gingival margin to the incisal edge for the incisors, to the buccal cusp tip for canines and premolars. In the case of molars, however, the distance from the tip of the mesiolingual cusp to the lowest point of the cementum-enamel junction or the free gingival margin was measured. The crown height, on the other hand, was defined as the distance between the occlusal line and the cementum-enamel junction (42).

The crown height is very significant during orthodontic bonding, as fixed orthodontic braces that have been pre-adjusted need to be ideally positioned to provide a pleasant smile and correct interdigitation. According to some researchers, the incisors' crown height significantly affects a patient's smile and plays an important role in facial attractiveness (43, 44).

When designing a smile during orthodontic planning, three aspects that must be considered: macro, mini, and micro aesthetics (45-47). Macro aesthetic involves assessing the relationships between the smile and the patient's facial features, such as the proportions of the teeth in releation to the lips, nose, and overall facial symmetry. Mini aesthetics involves assessing the size, shape, and alignment of each tooth that can impact the overall harmony of the smile. Microaesthetics involve the finest details of the smile, such as tooth texture, surface irregularities, and color.

1.2 Tooth size discrepancy (TSD)

Tooth size discrepancies (TSD) are commonly characterized as a significant redundancy of dental tissues in one dental arch compared to the opposite jaw (48), but also as a disparity in the sizes of specific teeth (7). Although natural teeth are well matched in most people, Proffit estimates that around 5% of the population has tooth size disparities (7).

To diagnose and treat orthodontic problems correctly, it is important to find out if there are TSD between the upper and lower jaws. As a result, orthodontic treatment plans are altered by decreasing (interdental reduction), enlarging (crowns or composites), or removing teeth before completion (49).

Orthodontists have used various methods to identify discrepancies between dental arches in patients. However, the Bolton analysis is the most well-known and popular technique, which is based on the ratios of the mandibular and maxillary mesiodistal tooth diameters (50).

1.2.1 Bolton analysis

In 1958, Bolton studied tooth size dimensions and their effect on occlusion. He developed a method for evaluating the maxillary-mandibular tooth width proportion to determine whether there is a dental discrepancy and how great it is. The analysis was based on 55 subjects, 11 of whom had excellent occlusion without orthodontic treatment. The sample, a collection of models, was collected from different private practices, the Department of Orthodontics, the School of Dentistry, and the University of Washington. By putting into proportion the summed mesiodistal widths of mandibular to maxillary teeth, he developed two ratios for estimating TSD: the anterior and overall ratios.

The analysis distinguishes between the 'overall ratio' of 91.3% (89.39-93.21), which involves all permanent teeth except the second and third molars, and the 'anterior ratio' of 77.2% (75.55-78.85), which encompasses only the six anterior teeth of each jaw (12). This was an effective way of measuring TSD, providing a reliable estimation for those afflicted with the condition.

Bolton analysis also tells us whether this discrepancy is located in the anterior segment or the entire dental arch. However, the analysis only gives the percentage of the discrepancy, not the size of the discrepancy in millimeters. Nevertheless, this method is still used as the standard analysis for evaluating dental discrepancies.

Furthermore, regarding the size of the discrepancy in millimeters, we also use two other formulas (the anterior discrepancy and overall discrepancy) to determine how many millimeters are missing or in excess for the normal placement of the teeth, whether this is the frontal segment or the entire dental arch.

1.2.2 Bolton's study regarding sex

The lack of a consistent pattern in tooth size variations indicates that tooth size ratios differ between dental arches in various populations.The variation in maxillary tooth size by population and sex does not correlate with differences in mandibular tooth size, so that distinct tooth size ratios are observed between arches (50).

Deviations from the average interarch relationship can be caused by a variety of factors. Among the local factors are the size of the upper lateral incisors, the central incisors, and the lower premolars. According to Lanio et al. (51), 75% of the sample (115 females and 85 males) had an anterior tooth size discrepancy. Many researchers have paid attention to the importance of the intermaxillary tooth width relationship in occlusion (12, 26, 50-58). Lundström (52, 53) introduced the anterior and overall intermaxillary indices as a percentage ratio, to investigate the presence of mesiodistal deviations that interfere with occlusion, particularly overbite and overjet.

Bolton (12, 54) reintroduced these indices and proposed the anterior, posterior, and overall ratios for the relationship between the mandibular and maxillary teeth. Bolton had observed that lower premolars tended to have larger mesiodistal dimensions than their antagonists. Neff (59), who proposed the anterior percentage relation (APR), made a similar attempt to evaluate the relationship between overbite and tooth size in the labial segments. The size of the upper six anterior teeth are divided by the size of the lower six anterior teeth. Many reports (55, 56, 60) have published similar figures for these ratios. Discrepancies between intermaxillary tooth sizes in different malocclusions have been studied (57, 60). The discrepancies were larger in class III and II occlusions than in class I.

In the dental literature, the majority of researchers (2-4, 8, 57, 60-77) have not reported sex differences in tooth size ratios. However, males and females differ in tooth size ratios (18), or only in the overall Bolton ratio (11, 78), or only in the overall and posterior tooth ratios (50, 79), or just in the anterior ratio (80), or only in the overall and anterior ratios (81).

These findings revealed considerable variation in the literature regarding tooth size ratios and sex. This suggests that these relationships occur more frequently in specific populations than in general.

1.2.3 Bolton's study regarding malocclusion groups and various populations

The relationship between tooth size ratios and malocclusion groups has been established since the last century, and has varying results. Numerous studies have determined Bolton's ratios in subjects with good or excellent occlusions in class I malocclusion; others have studied them between different malocclusion groups (classes I, II and III) according to the Angle classification (82) based on occlusal relationship, and Steiner's ANB angle (83) based on skeletal relationship. These are presented in Table 1.

Researchers worldwide have conducted studies to determine Bolton's ratios in different populations. Some studies suggest that the Bolton's ratio can be applied to a specific population, while others argue otherwise, emphasizing the need to consider regional influences when determining the ideal ratio. Overall, these studies have provided a wealth of information regarding the values of Bolton's ratios in different populations, and have highlighted the need to consider regional influences when determining the ideal Bolton's ratio.

It is important to note that in some cases, Bolton's ratios are not applicable. For example, in cases of extreme malocclusion, the Bolton's ratio cannot be accurately calculated. In such cases, the clinician must rely on other measures to determine the ideal ratio.

Further, most have suggested that Bolton's analysis is a very important tool in diagnostic orthodontics, and that it is an easy method to apply clinically. Therefore, doctors should apply it in order to avoid difficulties at the end of the orthodontic treatment.

Table 1. Anterior and overall tooth size ratios in different malocclusion groups and populations

Author	**Year of publication**	**Population**	**Occlusion**	**Sample size**	**Anterior ratio (%)**	**Overall ratio (%)**
Lundström (52)	1954	Swedish	-	140	78.5	92.3
Bolton (12)	1956	American orthodontic and non-orthodontic	Class I	55	77.2	91.3

Crosby and Alexander (60)	1989	American orthodontic	Class I, II, and class II surgery	109	77.5	91.4
Freeman et al. (84)	1996	American orthodontic	No data	157	77.8	91.4
Nie and Lin(57)	1999	Chinese orthodontic	Class I, II, and III	300	81.52	93.27
Santoro et al. (61)	2000	Dominican orthodontic	No data	54	78.1	91.3
Smith et al. (50)	2000	American orthodontic	-	180	79.6	92.3
Ta et al. (56)	2001	Chinese schoolchildren	Class I, II, and III	110	77.5	90.9
Alkofide and Hashim (63)	2002	Saudi Arabian orthodontic	Class I, II, and III	240	78.86	92.61
Araujo and Souki (62)	2003	Brazilian orthodontic	Class I, II, and III	300	78.2	No data
Redahan and Lagerström (85)	2003	Swedish orthodontic	Different malocclusions	137	78.0	No data
Al-Tamimi and Hashim (86)	2005	Saudi Arabian orthodontic	Normal	65	77.4	91.4
Nourallah et al. (87)	2005	Syrian orthodontic	Class I	55	78.99	92.26
Uysal and Sari (78)	2005	Turkish orthodontic	Normal, Class I, II, and III	860	78.63	91.30

Paredes et al. (65)	2006	Spanish orthodontic	Class I	100	78.32	91.97
Bernabé et al. (88)	2004	Peruvian schoolchildren	Class I, II, and III	200	78.1	90.8-91.3
Akyalçin et al. (89)	2006	Turkish orthodontic	Class I, II, and III	152	78.15	91.34
Al-Khateeb and Alhaija (90)	2006	Jordanian schoolchildren	Class I, II, and III	140	78.2	91.3
Fattahi et al. (80)	2006	Iranian orthodontic	Class I, II, and III	200	79.01	91.68
Endo et al. (8)	2007	Japanese orthodontic	Class I, II, and III	60	78.39	91.6
Mirzakouchaki et al. (91)	2007	Iranian-Azari orthodontic	Class I	50	78.0	92.0
Al-Omari et al. (67)	2008	Jordanian schoolchildren	No data	367	78.6	92.2
Wędrychowska-Szulc et al. (92)	2009	Polish orthodontic	Class I, II, and III	600	78.8	91.8
Strujić et al. (93)	2009	Croatian orthodontic	Class I, II, and III	301	78.06	91.64
Oktay and Ulukaya(81)	2009	Turkish orthodontic	Normal, class I,II,III	500	78.38-79.24	91.63-92.92
Lopatiene et al. (94)	2009	Lithuanian orthodontic	Class I, II, and III	181	78.88	92.73

Kachoei et al. (69)	2011	Iranian schoolchildren	Class I	54	78.10	92.24
Al-Gunaid et al. (70)	2012	Yemeni Arabians orthodontic	Class I, II, and III	176	78.1-78.0	92.00-92.2
Hyder et al. (71)	2012	Bangladeshi orthodontic	Class I, II, and III	120	78.2	90.94
Ricci et al. (72)	2013	Brazilian orthodontic	Class I, II div.1	105	77.30-77.3	90.36-90.76
Khan et al. (95)	2013	Libyan orthodontic	Class I, II, and III	115	78.64	91.22
Jindal and Bunger (96)	2013	Indian schoolchildren	Class I, II, and III	300	79.82	92.75
Zerouaoui et al. (97)	2014	Moroccan orthodontic	Class I, II and III	90	78.5	92
Cançado et al. (49)	2015	Brazilian orthodontic	Class I, II, and III	711	77.2	91.3
Hashim et al. (3)	2015	Sudanese orthodontic	Class I	60	76.9	90.8
Bugaighis et al. (74)	2015	Libyan schoolchildren	Class I, II, and III	343	78.2	91.3
Ismail and Abuaffan (73)	2015	Sudanese orthodontic	Normal, Class I, II, and III	196	77.46	91.47
Mujagić et al. (75)	2016	Bosnian orthodontic	Class I, II, and III	300	78.16	90.87

Hashim et al. (4)	2017	Qatari orthodontic	Class I, II, and III	100	78.6	91.8
Saritha et al. (76)	2017	South Telangana orthodontic	Class I, II, and III	311	79.17	92.3
Mohammad et al. (98)	2018	Saudi Arabian orthodontic	Normal, Class I, II, and III	521	77.05-78.54	91.41-91.56
Machado et al. (2)	2018	Portuguese orthodontic	Normal, Class I, II, and III	168	78.3	92.1
Mollabashi et al. (79)	2019	Iranian orthodontic	Normal, Class I, II, and III	300	78.51	92.36
Mishra et al. (77)	2019	Nepalese orthodontic	Normal, Class I, II,	120	78.4	91.4

1.2.4 The prevalence of clinical tooth size discrepancy (TSD) in various populations with different malocclusion groups

Bolton (54) suggested in 1962 that a deviation in TSD from the average of over 1 SD indicates the requirement for diagnostic attention. His study found that 29% of his private practice patients had TSD of over one standard deviation.

According to his study analysis, for the anterior ratio = 77.2%, the SD is 1.65%; if the anterior tooth ratio is less than 75.55%, this indicates an excess of maxillary anterior tooth material.
In contrast, if the anterior tooth ratio is greater than 78.85%, this indicates an excess of mandibular anterior tooth material.
For an overall ratio of = 91.3%, the SD is 1.91%, but if the ratio is less than 89.39%, this indicates excess tooth material in the maxilla. However, if the ratio is above 93.21%, this indicates an excess of mandibular tooth material (54).

In contrast, other researchers have interpreted this differently, as deviations of more than 2 SD from the Bolton standard (93). Accordingly, several studies have defined the prevalence of TSDs and report different results, as shown in Table 2. The prevalence of anterior TSD in permanent dentition is between 4.8% and 37.9%, while the prevalence of overall TSD ranges from 0.4% to 48% (Table 2).

Table 2. List of studies that show the frequency of TSDs (%) in different populations

Author	Population	Anterior TSD (%)	Overall TSD (%)
Crosby and Alexander (60)	American orthodontic	22.9%	-
Freeman et al. (84)	American orthodontic	30.6%	13.4%
Richardson and Malhotra (26)	American orthodontic	33.7%	-
Santoro et al. (61)	Dominican orthodontic	28%	11%
Ta et al. (56)	Chinese schoolchildren	8%	-
Bernabé et al. (88)	Peruvian schoolchildren	20.5%	5%
Uysal and Sari (78)	Turkish orthodontic	21.3%	18%
Endo et al. (8)	Japanese orthodontic	14.4%	6.7%
Araujo and Souki (62)	Brazilian orthodontic	22.7%	-
Othman and Harradine (14)	UK orthodontic	17.4%	5.4%
Wędrychowska-Szulc (92)	Polish orthodontic	31.2%	10.2%

Al-Gunaid et al. (70)	Yemeni Arabians orthodontic	29.53%	14.20%
O'Mahony et al. (68)	Irish orthodontic	37.9%	-
Al-Omari et al. (67)	Jordanian schoolchildren	23.7%	9.5%
Akyalçin et al. (89)	Turkish orthodontic	No data	48%
Strujić et al. (93)	Croatian orthodontic	16.28%	4.32%
Oktay and Ulukaya (81)	Turkish orthodontic	28.2 %	11%
Johe et al. (99)	American orthodontic	17%	12%
Bugaighis et al. (74)	Libyan schoolchildren	3%	4.2%
Hyder et al. (71)	Bangladeshi orthodontic	31%	11.6%
Sunitha and Naveen (76)	South Telangana orthodontic	33.8%	5.5%
Ajami et al. (100)	Iranian orthodontic	34.7%	20.7%
Mohammad et al. (98)	Saudi Arabian orthodontic	4.8%	0.4%
Mishra et al. (77)	Nepalese orthodontic	22.5%	9.1%

Several studies have found associations between TSDs and different malocclusion groups in Japanese (8), Chinese (56, 57), American (84), Dominican (61), South Telangana (76), Iranian (79, 80), Turkish (81), Peruvian (88), Croatian (93), Saudi Arabian (63, 98) populations, as shown in Table 3. In contrast, other studies (2, 49, 60, 64, 68, 70-73, 75, 77, 78, 89, 90, 94, 97, 101) did not report statistically significant differences (Table 3).

Table 3. List of studies showing a statistically and no statistically significant correlation between the TSDs and various malocclusion groups in different populations

Author	Population	Statistically significant differences
Freeman et al. (84)	American orthodontic	yes
Santoro et al. (61)	Dominican orthodontic	yes
Bernabé et al. (88)	Peruvian schoolchildren	yes
Endo et al. (8)	Japanese orthodontic	yes
Araujo and Souki (62)	Brazilian orthodontic	yes
Nie and Lin (57)	Chinese orthodontic	yes
Ta et al. (56)	Chinese schoolchildren	yes
Alkofide and Hashim (63)	Saudi Arabian orthodontic	yes
Oktay and Ulukaya (81)	Turkish orthodontic	yes
Fattahi et al. (80)	Iranian orthodontic	yes
Mirzakouchaki et al. (91)	Iranian –Azari orthodontic	yes
Strujić et al. (93)	Croatian orthodontic	yes
Saritha et al. (76)	South Telangana orthodontic	yes
Mohammad et al. (98)	Saudi Arabian orthodontic	yes
Mollabashi et al. (79)	Iranian orthodontic	yes
Crosby and Alexander (60)	American orthodontic	no

Basaran et al. (64)	Turkish orthodontic	no
Qiong and Jiuxiang (101)	Chinese orthodontic	no
Al-Khateeb et al. (90)	Jordanian orthodontic	no
Uysal et al. (78)	Turkish orthodontic	no
Akyalçin et al. (89)	Turkish orthodontic	no
Lopatiene et al. (94)	Lithuanian orthodontic	no
Al-Gunaid et al. (70)	Yemeni Arabian orthodontic	no
Hyder et al. (71)	Bangladeshi orthodontic	no
O'Mahony et al. (68)	Irish orthodontic	no
Ricci et al. (72)	Brazilian orthodontic	no
Zerouaoui et al. (97)	Moroccan orthodontic	no
Ismail and Abuaffan (73)	Sudanese orthodontic	no
Cançado et al. (49)	Brazilian Orthodontic	no
Mujagić et al. (75)	Bosnian orthodontic	no
Machado et al. (2)	Portuguese orthodontic	no
Mishra et al. (77)	Nepalese orthodontic	no

Consequently, from the literature, it was noted that TSDs vary between different populations with different malocclusion groups. Hence, population-specific standards are very important to achieve optimal orthodontic results (76).

Clinicians should be aware of the high prevalence of TSD when diagnosing and designing treatment plans for patients looking for orthodontic treatment. Hence, routine performance of a Bolton's analysis, regardless of malocclusion group, sex, and ethnicity, is highly recommended (99, 102).

1.3 Little's incisor irregularity index, overjet, and overbite

1.3.1 Little's irregularity incisor index

Crowding of the anterior teeth is one of the most common signs of malocclusion (103) and is one of the primary reasons for patients seeking orthodontic treatment (104, 105). Although crowding does not determine the orthodontic treatment needed, it is an important factor to consider (106). Generally, it seems agreed that dental crowding is a multifactorial condition that cannot be caused by one specific cause alone (104). It is nevertheless important that the orthodontic treatment plan addresses as many of the patient's concerns as possible (107).

There is considerable demand for orthodontic treatment due to aesthetic expectations related to the crowding of the maxillary incisors (108). However, their exposure decreases with age, making the mandibular incisors' crowding more visible. This can also affect the appearance of the smile (109).

On the other hand, according to Buschang (110), crowding of the lower incisors is common, with up to 40% of the general population having moderate to severe crowding. An analysis of changes in occlusal characteristics in 27 individuals by Tibana et al. (111) found no significant sexual dimorphism.

The literature describes several techniques for quantifying crowding for epidemiological purposes. The irregularity index was proposed by Little (103) as a viable and consistent quantitative technique for measuring lower anterior crowding. Using this index, he calculated the rate of initial mal relationship and the outcome of initial crowding post-treatment and post-retention.

1.3.2 Overjet and Overbite

Orthodontists usually measure the overjet and overbite as part of the routine orthodontic diagnosis. Nonetheless, both values need to be assessed accurately, as they indicate the sagittal relationship between the central incisors in the upper and lower jaws.

It has been found in studies that the relationship between the upper and lower incisors from a vertical and horizontal perspective varies at different stages of facial development (111). A study of occlusal changes at every stage of a person's growth can be beneficial to orthodontists (112). According to Tibana et al. (111), orthodontists should know how occlusion varies during all growth phases.

The bite structure and teeth's position in the mouth continually change throughout a person's growth until adulthood, according to Björk. Teeth, dental arches, and their relationship, i.e., occlusion, change, as do their shapes and sizes (113).

A number of longitudinal studies published in the past few years have revealed increases in overjets and overbites between sexes during the replacement of deciduous dentition (113-115). A study by Sinclaire and Little (115) revealed that the occlusal characteristics of females changed more severely than those of males.

In their longitudinal study of 33 sets of plaster casts of 18 females and 15 males aged 7 to 32, Heikinheimo et al. (116) reported that overjet increased in Finns with normal occlusions between ages 7 and 10. Thereafter, in males and females, there was a continual decrease up to age 32, peaking between 12 and 15. In contrast, they found that among females aged 7 to 32, overbite increased, while it decreased in males. However, in both sexes, overbite increased between ages 7 and 12.

In his longitudinal study of overbites from ages 8 to 20, in 60 individuals (30 males and 30 females), Bergersen (117) noted that overbites decreased as the second and the third molars erupted during the teenage years. Furthermore, he found no differences between the overbites of males and females aged 8 to 20. Among 27 individuals (14 women and 13 men) aged 21 to 28 years, Tibana et al. (111) discovered no changes in the overjet but an increase in the overbite at the completion of the observation time. However, no sexual dimorphism was observed.

Björk (113) noted that the variability of the overjet in Swedish boys was higher compared to the overbite at ages 12 and 20. The overjet usually alters with age, causing the mandible's

anterior teeth to migrate forward relative to the maxilla. These typical aging changes are minor. However, differences among individuals, reflected in aging, are relatively high.
Meanwhile, other authors have studied and described the sex and aging-related changes of the bite in growing individuals, utilizing dental casts or a series of radiographs (113, 115, 118, 119). In the opinion of Björk (113), the variations in an individual's bite during growth are attributed to dental, facial, and cranial development. Consequently, chewing, breathing, speaking, and mimicking contribute to forming or modifying the bite characteristics.

1.4 Dental arch dimensions

Dental arch dimensions, including dental arch width, length, depth, form, and palatal dimensions, are important for the diagnosis, treatment planning, and treatment outcomes in patients seeking orthodontic treatment at all ages. A number of researchers have investigated the dimensions and relationships of dental arches in various ethnic groups and geographic regions around the world (120-123).
Quantitative mathematical formulas or qualitative geometric forms usually describe the dental arches. The natural balance of the jawbone, alveolar bone and surrounding muscles gives it its shape and size. A variety of factors can affect their development, including heredity, bone growth, eruption, rotation, inclination of the teeth and the environment (90, 124, 125).
In orthodontics, measuring and defining the dental arches' size and shape is crucial to diagnosis and planning treatment. As a result, it affects the dentition's available space, esthetics, functioning, and long-term stability (126).

1.4.1 Arch width

Dental size and shape are particularly interesting to orthodontists and prosthodontists in the clinical dental field. Dental arches have been studied directly or indirectly in the discipline of anthropology, and the measurements have been used in direct methods (127, 128). The study of arch width has been a topic of great importance in orthodontic diagnosis and treatment because, according to Proffit, growth in the transverse plane during childhood and adolescence play a significant role in determining the size and shape of the jaws, as well as the overall arch width (126). Therefore, any further changes would generally require orthodontic or orthopedic treatment, to modify or correct the arch width.

Different investigators worldwide have described several landmarks and reference points for measuring dental arches in the maxilla and mandible, according to Ling and Wong (128). However, a unified consensus on the measured width of the dental arch has yet to be achieved. Moreover, most studies have measured the width of the dental arches across the permanent canines, premolars, and first molars at the cusp tips, central fossa, contact points, or the greatest distance between the buccal surfaces (128). Consequently, comparing the various studies has been challenging.

Previous studies have shown that the dental arch undergoes various dimensional changes over time. The most significant modifications occur during growth processes. However, it is well-recognized that these changes do not stop with the onset of adulthood, but continue more slowly, as evidenced by studies conducted throughout the life of an individual (129-131).

Numerous studies have studied the transversal development of the mandibular and maxillary bases, as well as changes in dental arch width (124, 126, 127, 133-136) predominantly based on class I samples or samples with a range of malocclusions (137).

According to some researchers' observations, the inter-canine and inter-molar distances increase until permanent dentition is complete, and reverse changes occur between early and middle adulthood. Furthermore, all observable alterations begin to reverse at this point, the inter-canine width tends to constrict, especially in the mandible (130-132, 136, 138). Other researchers, on the contrary, report that the inter-molar distance remained constant (115, 135) despite an increase in the upper arch between young adult and adult females (132).

Regarding sex, it was observed that males have wider arch widths than females. Moreover, other studies have found that the sexes differ in different malocclusions and populations.

1.4.2 Arch length

Since most orthodontic patients are growing children, knowledge of growth becomes important in determining etiology, outlining treatment procedures, and defining the likely outcome of treatment (139). Growth and treatment can affect the size of the dental arch, and these changes must be carefully taken into account by the orthodontist during treatment planning (130).

Several authors have investigated and reported changes in dental arch length during childhood, adolescence, and adulthood. Barrow and White (139) conducted an investigation that aimed to determine the arch length of 51 children whose dentition was in the primary, mixed, and permanent stages, according to the Angle classification, in a long-term study of maxillary and mandibular arch development. Moreover, it was found that the length of the dental arches decreased in many cases at the ages of 17 or 18. This may be explained by: 1) closure of the interproximal spaces of the posterior teeth, 2) lingual tipping of the anterior teeth, especially the upper incisors, and 3) normal wear on all proximal surfaces of the teeth. Over time, permanent teeth move and wear in various ways, leading to the shortening of the dental arch.
A better understanding of how arch length changes naturally over time may help to clarify this important clinical issue (130).
In their long-term cast study, Brown and Daugaard-Jensen (140) studied the changes in arch length in dentition during a person's adolescence and into early adulthood. The sample consisted of forty individuals, of whom 16 had received orthodontic treatment and 24 had not, and the occlusal relationships of the first permanent molars and the canines were evaluated, according to Angle. They estimated the arch length as a line from the anterior midpoint perpendicular to a transverse line connecting the two points used for measuring the inter-molar width. Their measurements showed that arch length decreases with increasing age. In the untreated group, 24 or 100% of the maxillary casts decreased in arch length. The mean decrease was 1.6 mm, ranging from 0.4 to 4.7 mm. In the mandibular casts, a decrease occurred in 23 casts or 95.8%. The mean decrease was 1.7 mm. The range fell between 0.1 and 3.8 mm. Meanwhile, the orthodontically treated group of 16 showed a similar decrease in arch length.
In a longitudinal study of dental development between the ages of 3 and 18, Morrees (134) reported that arch length decreased in both males and females, with the greatest decrease occurring between the ages of 9 and 14, corresponding to the replacement of the deciduous by the permanent dentition. The decrease was more variable, but generally greater in females than males, but the arch length remained constant after 14 years of age in both sexes.
Sinclair and Little (115) evaluated dental arch length in 65 persons with normal occlusions in mixed dentition, early permanent dentition, and early adulthood. Their results showed that both males and females demonstrated significant reductions in the length of the arch over the periods of mixed dentition and early permanent dentition. The length of the arch decreased over time.

The changes in females were greater than in males. Since the stability of treatment results is of paramount importance to both patients and clinicians, a greater understanding of these changes could influence the patient's expectations, and the treatment and retention plans designed by the clinician (130).

Bishara et al. (141) studied cephalometric and dental arch alterations in teenagers aged 13 to 25. They discovered an increase in tooth size-arch length discrepancy with age in both arches, resulting in arch length decreases over these years.

Furthermore, a long-term study of arch length in the upper and lower jaws was carried out by Bishara et al. (130) over 45 years, in people between 6 weeks and 45 years. Males had considerably greater total arch length of both arches than females, according to their findings. In addition, incremental maxillary and mandibular arch length improvements occur as a child develops until the age of two. The maxillary arch length continues to grow up to 13 years of age, and the mandibular arch length increases until eight years of age. After these ages, both males and females experienced considerable decreases in arch length up to the age of 45. Between the ages of 13 and 45, maxillary arch length decreased by 5.7 mm in males and 4.6 mm in females, while mandibular arch length decreased by 5.0 mm in both sexes.

Buschang et al. (142) measured arch length in 386 untreated adult females aged between 17 and 68, according to their age group and type of malocclusion (class I, class II, division 1, and division 2). The findings revealed that the younger adults had considerably greater dental arch sizes in the maxilla and mandible (17 to 25 years). Among the oldest group, the arch shape was shorter and wider. Class I subjects had slightly smaller arches than class II division 1 subjects. Maxillary arches in women in class II division 1 were the longest and narrowest, while those in class II division 2 were the shortest and widest. On the other hand, there were no significant changes in mandibular arch shape between the three classes.

Mills (143) determined the arch length for 230 young adults (17 to 21 years) with molar neutro-occlusion at the United States Naval Academy in Annapolis, Maryland. According to the results, the arch length did not differ between people with and without tooth misalignment. Alam et al. (144) inspected arch lengths in 53 subjects (aged 16 to 35 years); in both the maxilla and mandibular arches, to determine how age and sex affect the arch length, measured with 3D CBCT imaging. They found that males showed higher values than females.

1.4.3 Arch depth

In modern dentistry, dental arch depth is significant in orthodontic diagnosis and treatment planning, both of which are based on prevention and early diagnosis of oral diseases (118). In dentistry and orthodontics, arch depth refers to the vertical dimensions of the dental arch within the oral cavity. It refers to the distance between the highest point of the dental arch (typically the tips of the upper and lower molars) and the lowest point (most commonly the curve of the palate in the upper jaw or the alveolar ridge in the lower jaw).

The human craniofacial skeleton and related dental arches change visibly as we grow, adapt and age. The transitional dentition changes relatively rapidly, but once the permanent dentition is established, lesser alterations continue to be detected (118).

The vast majority of previous research has studied the growth changes that occur during the juvenile and adolescent periods (114, 124, 127, 139, 145-147). Some studies have investigated adult growth, and changes in adulthood (118, 142).The literature reviews also show that arch depth declines with age (124, 127, 140, 146, 148), at least up to age 26 years (135).

Brown and Daugaard-Jensen (140) measured arch depth in a sample of casts of 24 untreated subjects during adolescence and early adulthood. They discovered a 1.6 mm average decrease in the depth of both the upper and lower arches.

Moorrees (149) investigated the annual changes in depth of the two dental arches. Totaling the mean decreases from 9 to 14 years of age revealed very small decreases in the upper and lower dental arches: 0.3 mm and 0.2 mm in boys and 0.8 mm and 0.7 mm in girls.

Knott (127) measured the dental arch depth of 29 children with good occlusion between the ages of 9 and 12 years, and annually after that up to at least 15 years of age. She discovered a 1.5 mm decrease in maxillary arch depth from 9 to 15 years. This was followed by an increase of 0.4 mm up to the age of 11 in males and 10 years in females, and a subsequent decrease of 1.9 mm in each case. On the other hand, the average depth decrease of the mandibular arch was roughly 3 mm in both sexes. In the age range of 12 to 15 years, all individual curvatures on both arches decreased and reached more than 3 mm. The depth of the upper arch was around 65 percent of the width at age 9 and about 60 percent at age 15. The change in indices was slightly larger in the lower arch.

An analysis of 16 males and 10 females with good occlusion by DeKock (135) reported that the mandibular and maxillary arch depths decreased with age. Males aged 12 to 15 experienced a 6% decrease, while those aged 15 and 26 experienced a 4% decline. Females aged 12 to 15 showed a 4.5% decline and those aged 15 to 26 showed a 4.2% decline. The mean values for males and females aged 12 to 26 show declining trends.

Buschang et al. (142) studied the arch depth in 386 untreated adult females aged 17 to 68 years, based on their age and malocclusion type (class I; class II divisions 1 and 2). They found that both maxillary and mandibular dental arch sizes were larger in the younger age group.

Using long-term dental casts from 53 patients, Carter and McNamara (118) examined how dental arches change from late adolescence to the late 50's or 60's of a person's life in untreated people. They discovered a significant decrease in arch depth in both dental arches and in both males and females. However, the difference was less than 3 mm. The continuous slight force of muscle droop or function could be the cause.

1.4.4 Arch form

Over the past century, dental arch forms have been studied intensively to increase our understanding of the common shape and size of the teeth in each race and population (123). The relative positioning of the teeth, alveolar bone, and denture base within the jaw determines the shape of the denture arch (150). According to some authors, the arch form is influenced by genetic, developmental, functional, and environmental factors (151-154).

A few authors attempted to describe the form of the dental arch in the late 19th and early 20th centuries. Bonwill (155) outlined a set of geometric principles that provided the form of an ideal arch. Hawley (156) adopted Bonwill’s principles by positioning the incisors in an ideal arch using a circle portion: the circle’s radius was equal to the combined mesiodistal width of the patient's central, lateral, and canine teeth.

Several authors have used various conic sections, such as the ellipse, parabola, trifocal ellipse, and catenary curve to characterize the arch shape (150, 157-160).

Black (151) described the arrangement of the upper teeth in the form of a semi-ellipse. On the other hand, Angle described the “true line of occlusion” as more or less a parabolic curve. Izard’s study (157) identified the frequency of arch forms as 75% elliptical, 20% parabolic, and 5% square or “U” shaped.

However, most studies have identified dental arch shapes as tapered, ovoid, and square, which Chuck first classified in 1932 (161). In general, the ovoid dental form (45% of people) is the most generally used in orthodontic practice, followed by the tapered shape (40%), and the square dental arch shape (15%) is the rarest (162). Furthermore, a unique arch form may not provide the optimal solution for an entire ethnic sample since diverse dental parameters must be considered. Specifically, the critical clinical criteria influencing arch dimensions are arch depth, cross-arch width, and dental perimeter (163).
The Angle class represents an important factor that may influence the dental arch shape, and it has been observed that class III patients have the most detectable arch form, while class I patients showed the least detectable arch shape (162). Concerning sex differences, on average, males have greater arch dimensions than females (164).
Several studies have sought to quantify and determine a geometric arch form on the basis of landmarks recorded in a coordinate system (165-169). Some others have used mathematical functions (168), and the polynomial functions of the fourth and sixth degree (170-172).

1.4.5 Arch perimeter

The dental arch perimeter is among the most important dental arch parameters for orthodontic diagnosis and treatment planning. It is defined as the distance measured around the dental arch from the mesial surface of the first permanent molar to the same point on the opposite side (173, 174).
Carter and McNamara (118) examined arch perimeter changes over the lifespan of 53 subjects from adolescence until the fifth age group. Their results from the University of Michigan Growth Study indicate that arch perimeter decreases from 17 to 48 years. Furthermore, the statistically significant decrease in maxillary arch perimeter over time was similar in males (1.8±1.2 mm) and females (2.0±1.2 mm). However, the mandibular arch perimeter decreased significantly more in males (2.4±1.2 mm) than the same perimeter in females (1.7±1.3 mm) from age 17 to 48. This continuous decrease in arch perimeter may have long-term effects on tooth position.
After evaluating longitudinal occlusal changes in 27 young adults with normal occlusion, Tibana et al. (111) demonstrated that the maxillary arch perimeter decreased by an average of 0.67 mm and the mandibular perimeter decreased by 0.71 mm.

In 2011, Kareem et al. (175) measured and compared the arch perimeter between class I and class II malocclusion groups in a sample of Kurdish young adults (100 pretreatment orthodontic models) aged 14 to 25. They found that arch perimeters in the maxilla and mandible of class I were significantly shorter than in class II division 1. However, class II division 2 showed no significant differences.

1.5 Palatal dimensions

The anatomy of the human palate was investigated in early studies of skeletal remains (176) and, because of its morphology and position, is one of the most important anatomical structures for determining the nature of the skeletal pattern (177). The hard palate consists of the palatine processes of the maxilla on the anterior side and the plates of the palatine bones on the posterior side. All of these bones meet in a cruciform suture system that includes the median and transverse palatal sutures (178). It is associated with the intermaxillary suture connecting the maxillary central incisors (179).

Jotania et al. (180) define the hard palate as the palate's bony component that comprises the palate's anterior part. It is an essential component of the human skull that helps to separate the oral and nasal cavities (181). It is also associated with and supported by dentition, particularly the maxillary teeth (182).

Several authors studied individuals' palate measurements from birth to adulthood more than a century ago, using different measurement methods. According to Backwin (183), the palate is relatively broad and flat in infancy, and palatal dimensions correlate poorly with each other and with body dimensions. The palatal height increases and the plane of maximum width shifts posteriorly. In contrast, the width-height index of the palate remains unchanged in the first year. Palatal height, length, and depth are influenced by several factors, including the size and shape of the jaws and the type of malocclusion (184).

However, heredity is thought to be a strong etiological factor in malocclusions in which palatal dimensions play a role, and it is suggested that appropriate orthodontic or orthopedic procedures should be used at an early age to reduce or prevent undesirable genetic influences on palatal width, depth, and length (185).

Palate height changes as a child grows, and increases continuously, at a greater rate between the ages of 5 and 16 (186). However, some studies have investigated palatal height in normal occlusion (176, 186-188) and different malocclusion groups (189).

In their study, Riquelme and Green (185) used the palatometer to measure the height (depth) of the palate from a plane coinciding with points A and B of the maxillary first permanent molars to the highest point of the midline palatal vault.

As Korkhaus first proposed, the palatal height index can be determined by combining the height and width parameters (190). There have been a few reports of palatal height index variations during normal occlusal growth (176, 191-193). In a study of 237 Iranian children and adolescents with normal occlusion, Amirabadi et al. (191) evaluated the palate height index over a period of time. A decrease in the palatal height index was observed between primary and mixed dentition, and an increase during the transition from mixed to permanent dentition.

Most importantly, orthodontic treatment procedures can influence the palate (194) because orthodontic therapy primarily requires modifications in arch dimensions to correct existing malocclusions. On the other hand, one of the goals of orthodontic treatment is the stability of post-treatment outcomes, since the arch form appears to return to its previous shape (184).

Many studies have compared the palatal dimensions between class I and II malocclusions (195-197), normal occlusion, and different malocclusion (189, 198-200).

On the other hand, sex may play a crucial role in palatal dimension determination and modification during developmental growth. The sexual dimorphism of palatal dimensions is observed in both kids and adults (201).

A few studies (136, 202, 203) have shown that men have significantly larger palate dimensions than women. In contrast, Al-Mulla et al. (204) indicated that the difference between males and females in the palatal depth of 50 maxillary study models was insignificant.

As part of modern dentistry, based on the prevention and early diagnosis of oral diseases, palatal changes have become increasingly significant in diagnosis and treatment planning in orthodontics. Alterations in arch dimensions that occur naturally throughout growth are utilized as comparative “gold standards” to differentiate changes caused by orthodontic treatment.

In addition to helping with diagnosis and orthodontic planning, these modifications also provide a degree of stability after retention (118, 136, 205).

Furthermore, understanding normal palatal dimension values can help researchers identify oral developmental disorders (187). Numerous studies have shown that ethnicity (203), dietary regimens (206), and environmental factors (136) all influence palatal dimensions. The facial and cranial features of each ethnic group and population vary (207, 208).

2. THE AIM AND HYPOTHESES

2.1 The problem statement

The problem statement addresses the need for a comprehensive understanding of dental morphology in the young population of Kosovo, specifically focusing on tooth morphology and dental arch dimensions. The research aims to accurately measure these aspects in subjects of different sexes and malocclusion groups.

While previous studies in different populations have explored tooth size variations using different measurement variables, such as mesiodistal, buccolingual, diagonal crown and crown height dimensions, a comprehensive investigation into dental dimensions and arch morphology, particularly in the context of sex, age, malocclusions, has not been conducted in the Republic of Kosovo. Therefore, conducting a detailed study on tooth size, tooth size discrepancies, and variations in dental arch dimensions in young individuals is imperative. This research holds clinical relevance and serves as a foundational resource for orthodontic diagnosis, treatment planning, as well as in forensic and anthropological sciences.

Dentists use various techniques to determine tooth size and dental arch dimensions, with manual measurements being the traditional approach for assessing linear dimensions. However, advanced technology is recognized as crucial for obtaining more comprehensive data. In this study, a digital caliper and a 3D orthodontic compass are used to determine the dimensions of tooth and dental arch morphology on the dental casts from the study population, with ongoing validation of the technique's accuracy.

2.2 The aim and objectives of the study

The aim of the study is to determine and compare the tooth size, tooth size discrepancy and dental arch dimensions among Kosovar school children in different malocclusion groups and both sexes.

The objectives of the study are:

1. To measure the tooth size dimensions (mesiodistal crown width, buccolingual crown width, diagonal crown width, and crown height) and to determine whether there is a statistically significant difference between different sex and malocclusion groups;

2. To determine the value of tooth size discrepancies (the anterior, posterior, overall ratio, and anterior and posterior discrepancies) according to Bolton's analysis, and to determine whether there is a statistically significant difference between different sex and malocclusion groups;

3. To assess the Little's incisor irregularity index, overjet and overbite values, and discover if there is a statistically significant difference between different sex and malocclusion groups.

4. To measure the dental arch dimensions (the width, length, perimeter, depth, arch form, and palatal dimensions) and to determine whether there is a statistically significant difference between different sex and malocclusion groups;

5. To assess the palatal height index values and find out if there is a statistically significant difference between different sex and malocclusion groups;

2.3 The hypotheses

1. There are significant differences between males and females in tooth size ratios and dimensions of dental arches.

2. There is a difference in the incidence of tooth size discrepancies among different malocclusion groups of Kosovar schoolchildren.

3. The dimension of the dental arches differs in respect of malocclusion.

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Sample design

The participants were Kosovo residents from seven regional cities (Prishtina, Gjilan, Prizren, Gjakovë, Pejë, Mitrovicë, and Ferizaj) randomly selected by multistage cluster sampling in 14 different elementary and high schools. The sample comprised 400 schoolchildren (216 females and 184 males) aged 13 to 19 years (mean age 15.17 years ±1.91 SD). The age range of the subjects was chosen to minimize the influence of tooth wear, caries, restorations, attrition and erosion. Participants were selected between April and September 2021. All participants who agreed to participate in this study were volunteers.

3.1.2 The study material

The study material consisted of 400 dental casts of Kosovar schoolchildren collected in seven private dental clinics in the Republic of Kosovo.

3.1.3 Selection criteria

The inclusion criteria were: Kosovar nationality, aged 13 to 19 years; all permanent teeth, except for the third molars, have fully erupted; no previous or ongoing orthodontic treatment; no tooth abrasion, attrition, or large restorations; no fractured teeth, no abnormal tooth morphology; and good quality study casts.

3.1.4 Sample size

According to the Kosovo Agency Statistics (KAS), there are 243,727 adolescents aged 13 to 19 years in the Republic of Kosovo (209). In this study, the sample size was calculated using the following formula (210):

$$Sample\ size = \frac{\frac{z^2 x\, p(1-p)}{e^2}}{1 + \left(\frac{z^2 x\, p(1-p)}{e^2 N}\right)}$$

N = 243727; e (margin of error) = 5%; Confidence level = 95%, z-score = 1.96; Sample size= 400

The sample resulted in 374 subjects, and this number was rounded to 400 subjects. The margin of error was assumed to be 5%, the confidence level was set at 95% and the z-score at 1.96.

3.1.5 Study design

This cross-sectional study (a type of prospective observational study) analyses data collected from the population at a specific point in time.

3.1.6 Sampling design

The study was divided into several phases. In the first phase, we randomly selected seven Kosovar cities that represented the main population. In the second phase, we visited seven prospective elementary schools and seven high schools to distribute invitation letters. In the third phase, the participants who met the criteria, had read the information letter, and signed the informed consent form were selected. In the fourth phase, we took dental impressions of each participant at private dental clinics in each city, and then the study models were made (phase 5). In the final phase, tooth size and dental arch dimensions were measured on dental casts (Figure 1).

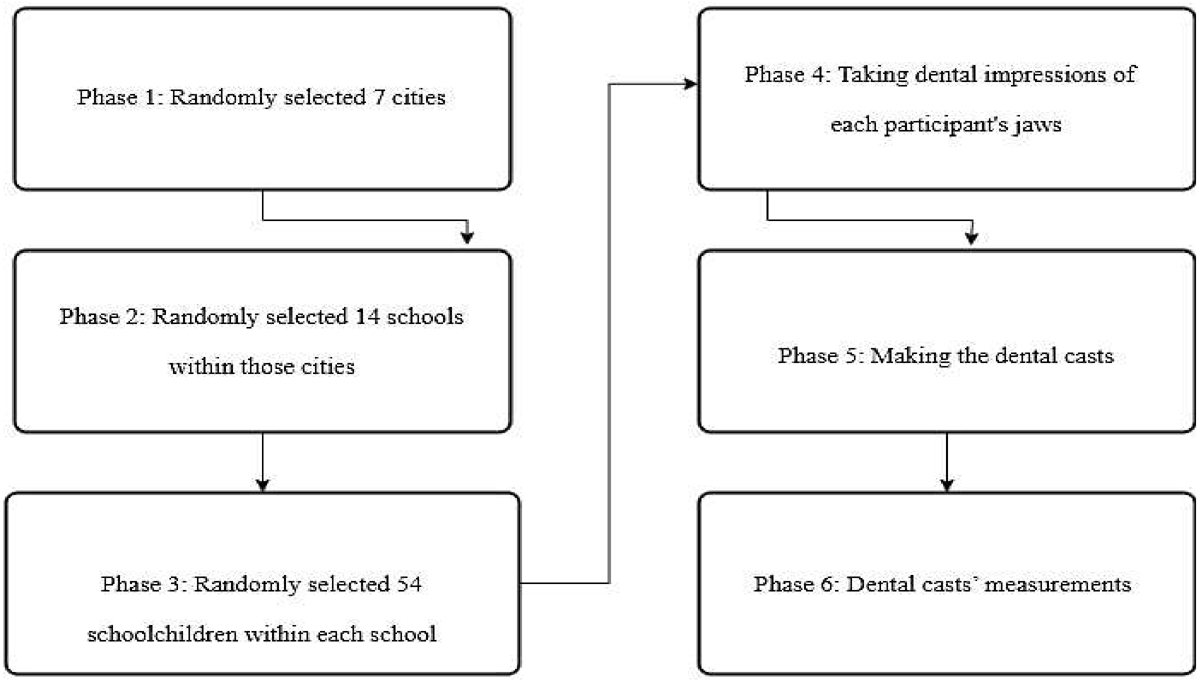

Figure 1. Study phases.

3.1.7 Sample selection

A total of 442 adolescents ranging in age from 13 to 19 were examined. As a result of a prior orthodontic treatment history, 27 subjects were excluded. 10 subjects were excluded because of missing tooth, while 5 other subjects were excluded because of large restorations in posterior teeth. A single examiner conducted the examination (B.Z.L) (Figure 2).

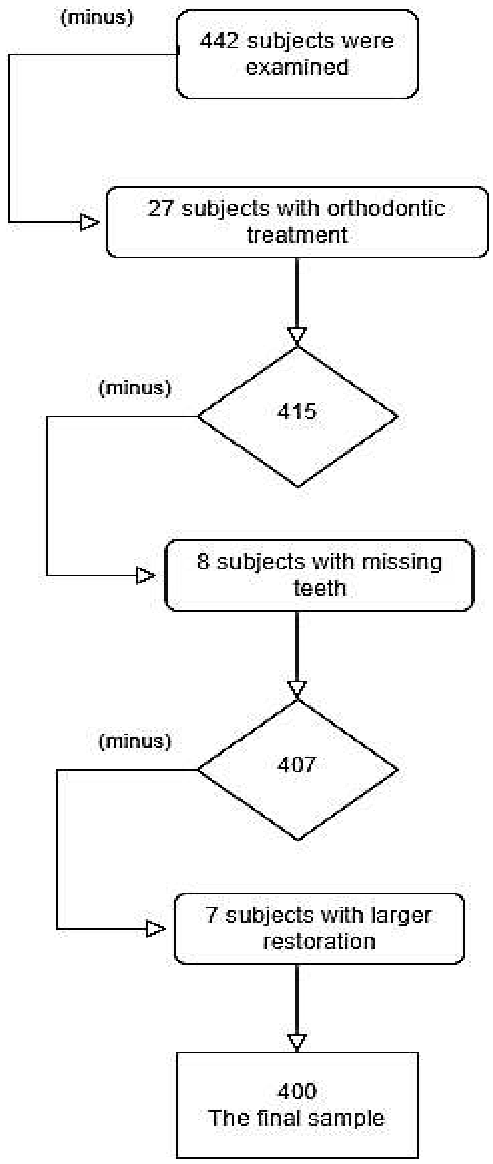

Figure 2. The flow of sample selection.

3.1.8 Confidentiality

All data were entered into a web application and the schoolchildren's confidentiality was ensured. Only the researcher and the mentors had access to the data. All study documents were given a specific number.

3.1.9 Ethical consideration

The Research Ethics Committee of the School of Dental Medicine of the University of Zagreb, Croatia, approved this research (05-PA-30-XXIII-1/2021). In addition, a permit was also obtained from the Education Office in each municipal city of the Republic of Kosovo and the seven private dental clinics.

3.2 Methodology

3.2.1 Dental cast measurements

After impressions had been taken of both dental arches with irreversible hydrocolloid material (alginate), the study casts were made in blue stone (Kromopan, Class A, type I, Lascod comp., ISO 21563, Firenze, Italy).

Measurements were taken directly from the dental casts using a digital electronic caliper (CD-6''ASX; Mitutoyo Corp., Kanagawa, Japan), accurate to 0.01 mm, and a three-dimensional orthodontic Korkhaus compass (028-350-00; Dentaurum GmbH, Ispringen, Germany) (Figures 3 and 4).

Each set of study casts was evaluated, with the maxillary cast being considered first, followed by the mandibular cast. The teeth, excluding the third molars, were measured from the maxillary right side to the maxillary left side, then to the mandibular left side and finally to the mandibular right side, ending with the most distal tooth. The FDI tooth notation system was used (211). After measuring the tooth size, the dental arch dimensions were measured, starting with the maxillary arch and then the mandibular arch.

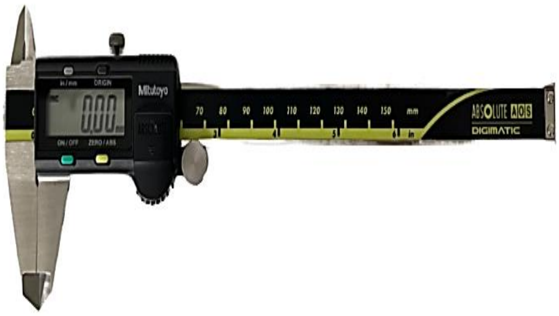

Figure 3. A digital caliper **Figure 4.** A 3D orthodontic Korkhaus compass

3.2.2 Tooth size measurements for the maxillary and mandibular arches

Measurements included:

- the mesiodistal crown widths of maxillary and mandibular teeth from the right second permanent molar to the left second permanent molar (93) (Figure 5).

- the buccolingual crown width was measured as the greatest distance between the buccal/labial and lingual surfaces perpendicular to the occlusal plane (29) (Figure 5).

- the diagonal crown width was measured as the largest distance between the mesiobuccal to the distolingual (MBDL) and the mesiolingual to the distobuccal (MLDB) points of the crown (29) (Figure 5).

- the crown height measurement was recorded on the buccal/labial surface as the greatest distance from the occlusal/incisal line to the cervical line parallel to the occlusal plane (41) (Figure 5).

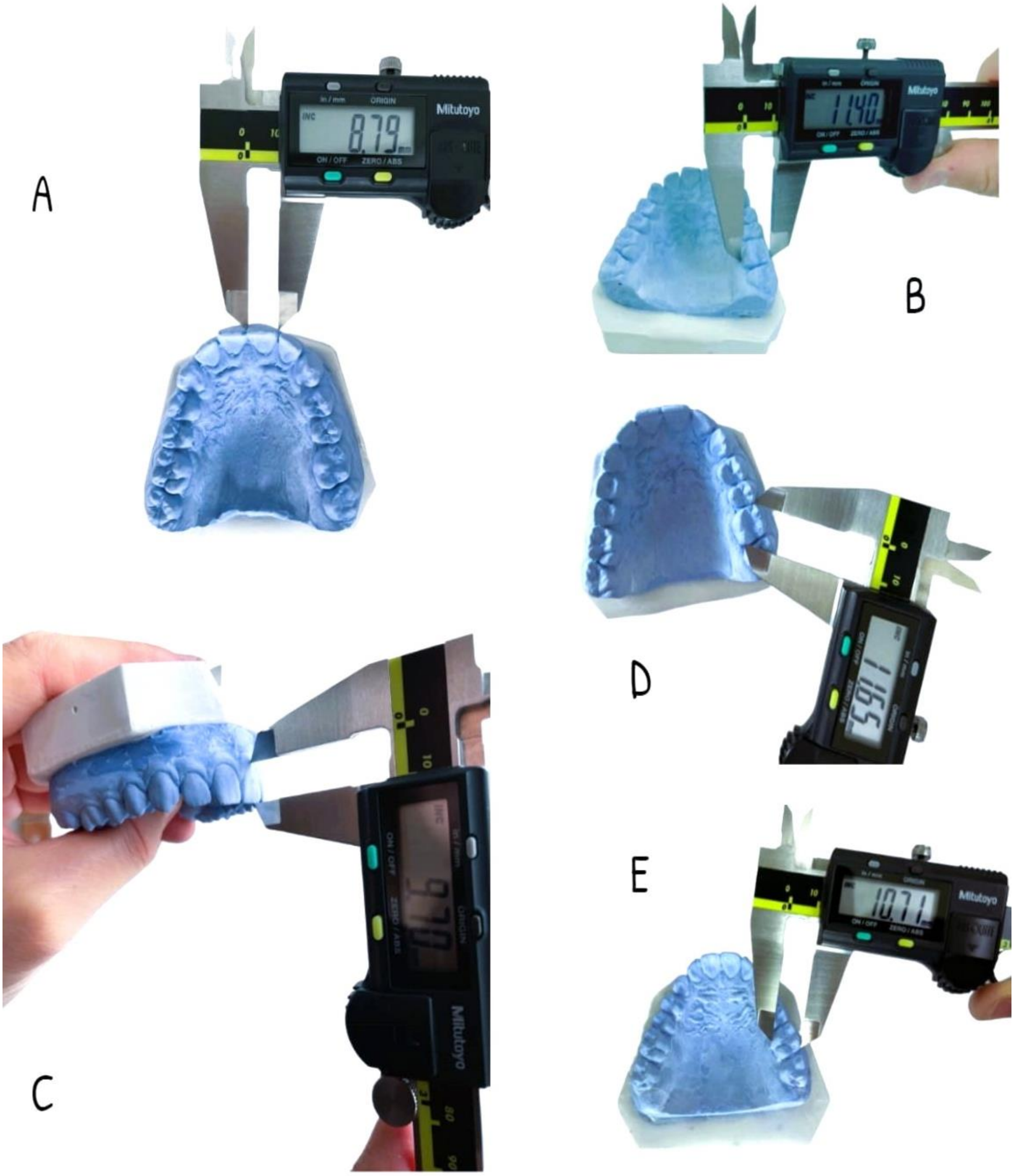

Figure 5. Measurements of tooth size dimensions. **(A)** MD width, **(B)** BL width, **C)** Crown height, **(D)** MBDL width, **E)** MLDB width.

3.2.3 The tooth size ratio and discrepancy were determined according to Bolton's analysis (12, 54):

The Bolton anterior ratio was calculated by dividing the sum of the MD widths of the lower and upper frontal teeth (from the right canine to the left canine). The result was then multiplied by 100.

$$anterior\ ratio = \frac{\sum (33 \leftrightarrow 43)}{\sum (13 \leftrightarrow 23)} x100$$

The Bolton overall ratio was calculated by dividing the sum of the MD widths of the lower and upper teeth (from the right first molar to the left first molar). The result was then multiplied by 100.

$$overall\ ratio = \frac{\sum (36 \leftrightarrow 46)}{\sum (16 \leftrightarrow 26)} x100$$

The Bolton posterior ratio was calculated by diving the sum of the MD widths of the lower and upper posterior teeth (from the first premolar to the first molar, on both sides of the jaws). The result was then multiplied by 100.

$$posterior\ ratio = \frac{\sum (36 \leftrightarrow 34, 44 \leftrightarrow 46)}{\sum (16 \leftrightarrow 14,\ 24 \leftrightarrow 26)} x100$$

The Bolton anterior discrepancy was calculated by summing the MD widths of the upper frontal teeth (from the right canine to the left canine). Divide the sum of the MD widths of the lower frontal teeth (from the right canine to the left canine) by 77.2, then multiply by 100. Then, the result was subtracted from the first sum to arrive at the result.

$$anteror\ discrepancy\ = \sum (13 \leftrightarrow 23) - (\frac{\sum (33 \leftrightarrow 43)}{77.2} x100)$$

The Bolton overall discrepancy was calculated by summing the widths of all upper teeth (from the right first molar to the left first molar). Divide the sum of the widths of all lower teeth (from the right first molar to the left first molar) by 91.3, then multiply by 100. Then, the result was subtracted from the first sum to arrive at the result.

$$overall\ discrepancy\ = \sum (16 \leftrightarrow 26) - (\frac{\sum (36 \leftrightarrow 46)}{91.3} x100)$$

To assess the irregularity of the upper and lower anterior teeth, we used Little's irregularity index. The degree of anterior irregularity was estimated by adding together the incisor and canine linear displacements (103) (Figure 6).

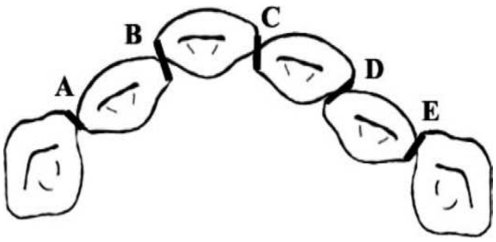

Figure 6. Assessing Little's irregularity index (A+B+C+D+E). Source: Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod. 1975; 68: 554–563.

Overjet was defined as the distance measured in the horizontal plane from the most anterior position of the maxillary central incisor's incisal edge to the labial surface of the mandibular central incisor (116) (Figure 7).

Further, overbite was determined in the vertical plane from the maxillary central incisor's incisal edge, to the mandibular central incisor's incisal edge where there is the highest overlap (117) (Figure 7).

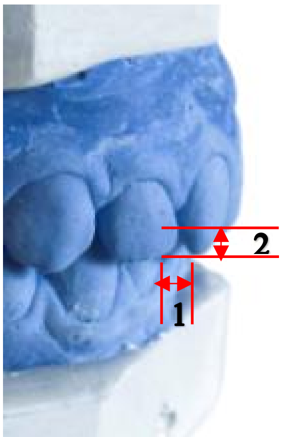

Figure 7. Measurements of: **1)** overjet and **2)** overbite.

3.2.4 Dental arch measurements

Measurement of arch width:

- The inter-canine distance was measured between the cusp tips of the right and left maxillary and mandibular permanent canines (29, 122, 136) (Figure 8).

- the inter-premolar distance was measured between the buccal cusp tips of the right and left maxillary and mandibular first and second permanent premolars (29, 122, 136, 212) (Figure 8).

- the inter-molar distance was measured between the mesiobuccal cusp tips of the right and left maxillary and mandibular permanent first molars (29, 122, 136) (Figure 8).

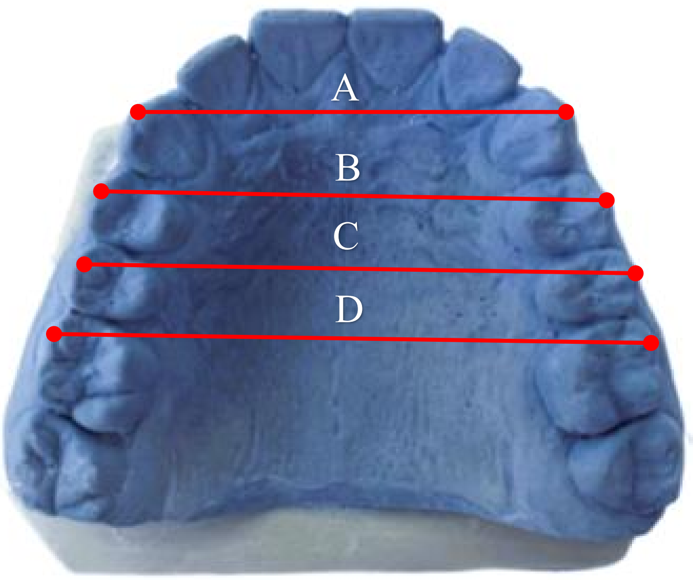

Figure 8. Measurements of arch width. (A) Intercanine width. **(B, C)** Inter-premolar width. **(D)** Inter-molar width.

Arch length was measured as the sum of triangular-shaped lines amongst the mesiobuccal cusp tips of the first permanent molars to the contact point of the central incisors, or the midpoint of the central incisors if they were spaced (29, 122, 213) (Figure 9).

Arch perimeter was measured as the sum of two bilateral arch length segments. The first segment is the distance between the distal measurement point of the first molar and the mesial contact point of the first premolar, while the second segment is the distance from the distal contact point of the canine to the mesial contact point of the central incisor (122) (Figure 9).

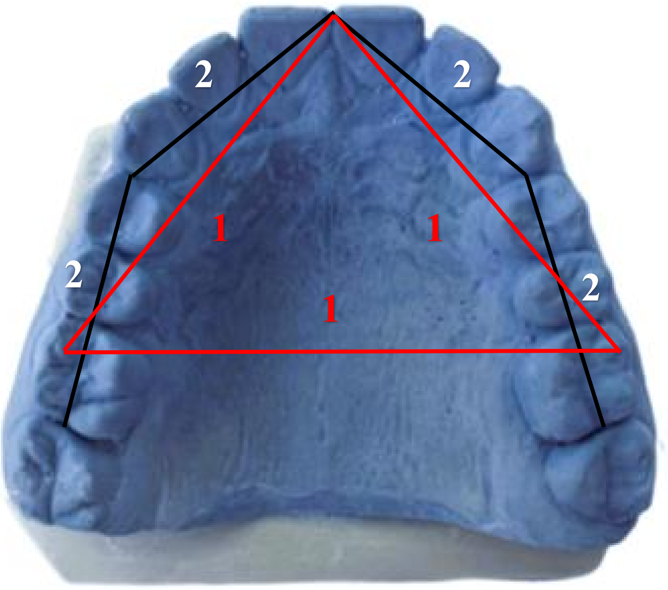

Figure 9. Measurement of **1)** arch length and **2)** arch perimeter.

The arch form for each cast was determined by measuring the inter-canine width (CW), canine depth (CD), intermolar width (MW), and molar depth (MD). Using these parameters, the arch form ratio was calculated on the basis of the arch form ratio formula:

Arch form = $\frac{CD}{CW} x \frac{MW}{MD}$ or $\frac{CD}{CW} x \frac{MD}{MW}$ (214) (Figure 10).

The application of this ratio to predict arch form was as follows:

1. if the ratio is less than 45.30%, a square arch form was expected;
2. if the ratio is between 45.30% - 53.37%, an oval arch form was expected;
3. if the ratio is more than 53.37%, a tapered arch form was expected.

Arch depth was determined using the formula: $\sqrt{\frac{AC^2+BC^2}{2} - \frac{AB^2}{4}}$ = CD = Arch depth (135) (Figure 11).

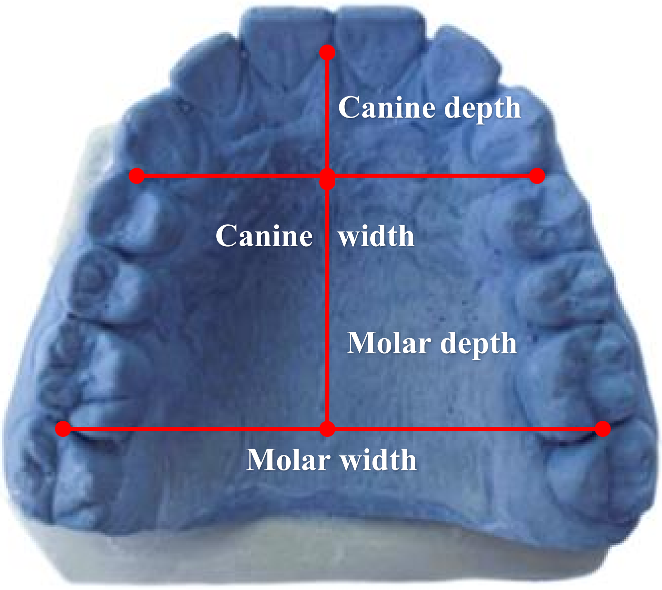

Figure 10. Measurement of arch form.

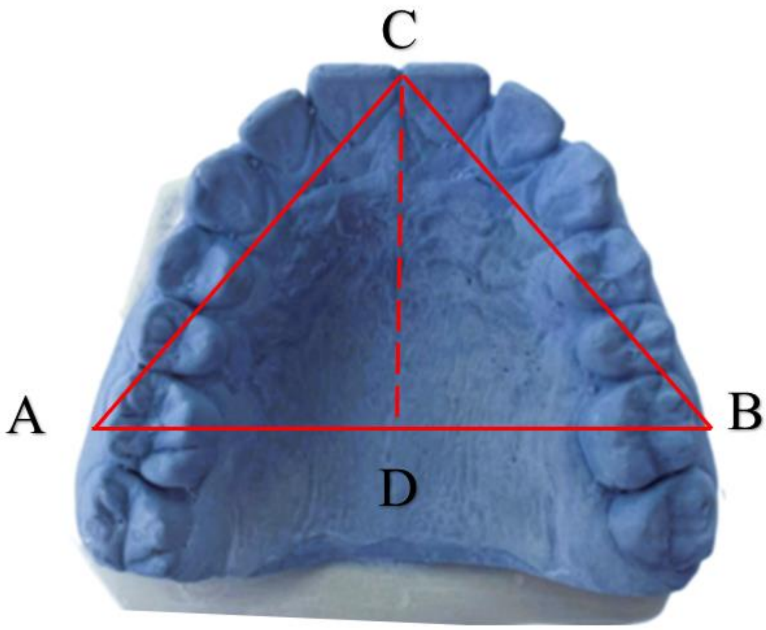

Figure 11. Measurement of arch depth: **AB**= arch width; **CD**=arch depth.

Palatal dimensions were assessed by measuring these linear dimensions (185):
Palate width was measured as the minimum distance between the upper first permanent molars at the cervical aspect of the mesio-palatal cusps on the junction of the tooth and gingival margins (points A and B, Figure 12a).

The length of the palate was measured from anterior point C, defined as the intersection of the mid-sagittal plane with a line passing over the widest point of the incisal papilla, to posterior point D, defined as the intersection of the mid-sagittal plane with a plane passing through the most distal points of the upper first permanent molars (Figure 12a).

The height (depth) of the palate was measured with the three-dimensional orthodontic Korkhaus compass from a height coincident with points A and B of the maxillary first permanent molars to the highest point of the midline palatal vault (Figure 12b) (185).

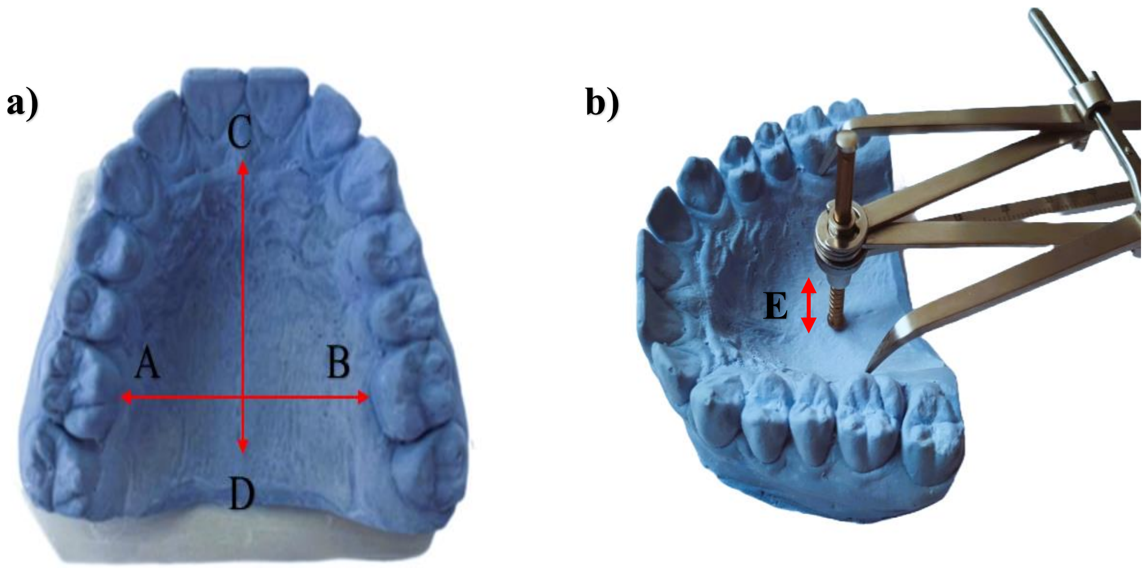

Figure 12. Measurement of palatal dimensions: **a)** (**A, B**) - palatal width; (**C, D**) – palatal length; **b) E** - palatal height (depth).

For the measurement of the palatal height index, the reference points included the central fissures of the upper first molars for measuring the palate's width and a vertical line coinciding with the distance between the central fissures of the upper first molars for measuring the height of the palate at its highest point on the midline palatal vault (Figure 13) (190).

The palatal height index was determined using the following formula:
Palatal height index $= \frac{palate\ height}{palate\ width} x100$ (190). The average index value is 42%. If the value is over 42%, then a high palate was expected. If the value is less than 42%, a shallow palate was expected.

Figure 13. Measurement of palatal height for calculation of the palatal height index.

3.2.5 Assessment of measurement errors

In order to assess the examiner's measurement error, the author (B.Z.L) measured 30 pairs of casts within a 24 hour post period. One examiner (B.Z.L) made all the measurements.

If the difference was less than 0.2 mm, the first measurement was registered. However, if the second measurement differed from the first by more than 0.2 mm, it was measured again and only the new measurement was registered.

The reproducibility of the measurements was analyzed using Dahlberg's formula (1940). The error was calculated using the formula ME=$\sqrt{d^2/2n}$, where d was the difference between duplicate measurements and n was the number of replications (215). The results are shown in Appendix A.

3.3 Statistical analysis

The statistical calculations were carried out using the Statistical Package for Social Sciences Version 25.0 (IBM SPSS, New York, USA).

The parametric or non-parametric data distributions were evaluated using the Kolmogorov - Smirnov test to see whether the sample was normally distributed or not.

All hypotheses were validated through two parametric statistical tests or two non-parametric statistical tests, namely: the T-test / Independent Sample T-test and the one-way ANOVA test, or the Mann Whitney U-test and the Kruskal-Wallis test.

Two parametric statistical tests (Independent Sample T-test and one-way ANOVA test) were used if the data had a normal distribution, and the non-parametric statistical tests (Mann Whitney U-test and Kruskal-Wallis test) if the data had a non-normal distribution.

Males and females were compared using the Independent Sample T-test and Mann Whitney U-test. The variations among the three classes of malocclusions were analyzed using ANOVA, Kruskall-Wallis, and Dunn's post-hoc test. A statistically significant p-value of 0.05 was used.

4. RESULTS

4.1 Data distribution and descriptive statistics

The sample of this study included 400 teenagers (216 girls and 184 boys) aged 13 to 19 years. The mean age of the participants was 15.17 years ±1.91 SD. Sample distribution by sex and malocclusion classes is presented in Tables 4 and 5. Regarding sex, the sample consisted of a majority of female participants.

Table 4. Characteristics of the participants (n=400)

	Sex, n (%)	**Mean age ± SD**
Male	184 (46%)	15.30±1.90
Female	216 (54%)	15.05±1.91
Total	**400 (100%)**	**15.17±1.91**

Table 5. The distribution of the sample according to sex, malocclusion groups and mean age (n=400)

	Class I	**Class II**	**Class III**	**Total**
Male	102	75	7	184
Female	110	91	15	216
Total	**212**	**166**	**22**	**400**
Mean age ± SD	14.95 ± 1.74	15.30 ± 2.04	16.22 ± 2.15	15.17 ± 1.91
Range	13-19	13-19	13-19	13-19

The Kolmogorov-Smirnov test showed that some variables had normal distribution, while others had non-normal distribution. Therefore, parametric and non-parametric tests were used for further analysis. Table 6 presents the variables that had normal and non-normal distribution of data.

Table 6. The data distribution of sample's variables

Variable	Tooth size and dental arch dimensions	The Kolmogorov -Smirnov test[a,b]
MD width	12,13,14,15,21,22,23,24,27,32,33,34,35,36,37,41,42,43 ,44, 46, 47	a
	11,16,17,25,26,31,45	b
BL width	11, 13, 14, 15, 16, 17, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33, 37, 43, 44, 45, 47	a
	12, 34, 35, 36, 41, 42, 46	b
MB-DL width	11, 12, 14, 16, 21, 23, 24, 25, 31, 32, 33, 34, 42, 43, 45, 46, 47	a
	13, 15, 17, 22, 26, 27, 35, 36, 37, 41, 44	b
ML-DB width	11, 12, 13, 14, 15, 17, 23, 24, 25, 26, 27, 31, 32, 33, 35, 37, 44, 45, 46, 47	a
	16, 21, 22, 34, 36, 41, 42, 43	b
Crown height	11, 13, 15, 17, 21, 22, 23, 24, 31, 32, 34, 35, 36, 37, 41, 42, 44, 45, 46	a
	12, 14, 16, 25, 26, 27, 33, 43, 47	b
Anterior ratio		b
Overall ratio		a
Posterior ratio		a
Anterior discrepancy		a
Overall discrepancy		a
LII		b
UII		b
Overjet		b
Overbite		b
Arch width maxilla		
C-C		a
P_1-P_1		a
P_2-P_2		a
M_1-M_1		a
Arch width mandible		
C-C		b
P_1-P_1		a
P_2-P_2		a
M_1-M_1		a
Arch length maxilla		a
Arch length mandible		a
Arch perimeter maxilla		a
Arch perimeter mandible		a
Arch form maxilla		b
Arch form mandible		b
Arch depth maxilla		a
Arch depth mandible		a
Palatal width		b
Palatal length		a
Palatal height (depth)		b
Palatal height index		a

a- *normal distribution;* ***b-*** *non-normal distribution*

Regarding the tooth size dimensions, Table 7 shows the mean values of the mesio-distal tooth width of maxillary and mandibular teeth.

Table 7. The descriptive statistics of mesio-distal crown width in millimeters

Tooth	N	Mean	Minimum	Maximum	SD	VAR
11	400	9.09	7.47	10.55	0.57	0.33
12	400	6.93	5.38	8.77	0.60	0.36
13	400	8.21	6.19	9.80	0.54	0.30
14	400	7.20	5.77	8.46	0.46	0.21
15	400	6.92	5.41	8.31	0.49	0.24
16	400	10.16	4.61	11.88	0.63	0.40
17	400	9.54	3.91	11.80	0.75	0.56
21	400	9.10	7.48	10.67	0.59	0.34
22	400	6.89	5.32	8.64	0.57	0.33
23	400	8.17	6.31	9.97	0.56	0.31
24	400	7.20	5.43	9.76	0.50	0.25
25	400	6.87	5.41	9.28	0.52	0.27
26	400	10.19	4.61	11.78	0.63	0.40
27	400	9.60	4.57	11.42	0.62	0.39
31	400	5.86	4.73	7.80	0.43	0.19
32	400	6.36	5.00	7.96	0.42	0.18
33	400	7.23	5.55	10.25	0.53	0.29
34	400	7.31	5.83	8.66	0.51	0.26
35	400	7.27	5.65	8.58	0.51	0.26
36	400	11.16	5.27	13.53	0.78	0.61
37	400	10.07	4.89	12.35	0.70	0.49
41	400	5.80	4.67	8.39	0.42	0.17
42	400	6.25	4.94	8.26	0.41	0.16
43	400	7.14	5.50	9.81	0.53	0.29
44	400	7.30	6.04	8.77	0.51	0.26
45	400	7.24	5.98	10.91	0.54	0.29
46	400	11.17	5.79	13.18	0.77	0.60
47	400	10.25	4.90	12.67	0.71	0.50

On the other hand, the descriptive results of the maxillary and mandibular buccolingual widths are shown in Table 8 below.

Table 8. The descriptive statistics of bucco-lingual crown width in millimeters

Tooth	N	Mean	Minimum	Maximum	SD	VAR
11	400	7.34	5.62	9.20	0.56	0.32
12	400	6.53	4.89	8.50	0.60	0.36
13	400	8.12	5.11	10.80	0.74	0.55
14	400	9.35	7.43	11.30	0.58	0.34
15	400	9.51	5.35	11.91	0.68	0.47
16	400	10.95	8.47	13.50	0.69	0.48
17	400	10.59	8.23	13.06	0.81	0.67
21	400	7.34	5.55	9.10	0.57	0.33
22	400	6.54	4.70	9.00	0.56	0.31
23	400	8.19	6.41	10.80	0.68	0.46
24	400	9.32	7.47	11.90	0.59	0.34
25	400	9.48	7.39	11.49	0.62	0.39
26	400	10.97	9.05	14.00	0.65	0.42
27	400	10.57	8.54	13.00	0.74	0.55
31	400	6.22	4.41	8.43	0.50	0.25
32	400	6.52	5.22	8.81	0.46	0.21
33	400	7.47	5.63	10.00	0.67	0.46
34	400	8.01	5.57	10.00	0.58	0.34
35	400	8.63	5.20	11.00	0.62	0.38
36	400	10.54	1.72	12.40	0.73	0.53
37	400	10.04	7.25	12.07	0.67	0.46
41	400	6.22	4.55	9.06	0.51	0.26
42	400	6.46	5.18	9.84	0.50	0.25
43	400	7.44	5.70	10.30	0.67	0.46
44	400	8.08	6.10	10.00	0.59	0.39
45	400	8.70	6.41	11.00	0.59	0.35
46	400	10.60	7.80	12.22	0.58	0.34
47	400	10.01	7.67	12.09	0.68	0.47

The following results in Table 9 present the general descriptive data for the diagonal crown width MBDL of the maxilla and mandible.

Table 9. The descriptive statistics of diagonal crown width MBDL in mm

Tooth	N	Mean	Minimum	Maximum	SD	VAR
11	400	9.24	7.31	11.40	0.63	0.40
12	400	7.37	5.67	9.73	0.66	0.44
13	400	7.63	6.20	9.55	0.60	0.36
14	400	7.60	6.17	9.20	0.47	0.22
15	400	7.76	6.21	11.06	0.51	0.26
16	400	11.50	7.98	13.50	0.64	0.42
17	400	10.34	7.82	13.19	1.00	1.00
21	400	9.24	7.31	11.84	0.63	0.40
22	400	7.41	5.39	9.50	0.67	0.45
23	400	7.58	5.80	10.12	0.65	0.42
24	400	7.41	6.06	9.00	0.46	0.22
25	400	7.52	6.13	9.00	0.47	0.22
26	400	11.56	8.30	13.50	0.65	0.42
27	400	10.28	7.67	13.03	1.01	1.03
31	400	7.05	4.53	9.31	0.71	0.50
32	400	7.18	5.07	9.22	0.65	0.42
33	400	7.38	5.25	10.53	0.67	0.46
34	400	7.04	5.82	9.05	0.50	0.25
35	400	7.45	5.88	9.40	0.53	0.29
36	400	10.66	6.58	12.90	0.66	0.44
37	400	10.07	5.78	12.31	0.71	0.50
41	400	7.08	5.02	9.44	0.72	0.52
42	400	7.30	4.41	9.76	0.67	0.46
43	400	7.51	5.34	10.13	0.68	0.46
44	400	6.95	5.76	8.90	0.51	0.26
45	400	7.28	5.88	9.50	0.52	0.27
46	400	10.82	7.89	12.90	0.57	0.32
47	400	10.13	7.14	12.60	0.67	0.46

The following descriptive results in Table 10 represent the mean diagonal crown width MLDB.

Table 10. The descriptive statistics of diagonal crown width MLDB in mm

Tooth	N	Mean	Minimum	Maximum	SD	VAR
11	400	8.54	6.46	11.00	0.62	0.39
12	400	6.88	4.98	8.90	0.64	0.41
13	400	7.33	5.52	9.20	0.56	0.32
14	400	7.88	6.56	9.50	0.46	0.21
15	400	7.83	6.27	9.60	0.47	0.22
16	400	9.93	6.83	12.36	0.71	0.51
17	400	9.00	6.78	11.80	0.73	0.53
21	400	8.38	6.41	10.63	0.63	0.40
22	400	6.76	4.91	9.00	0.61	0.38
23	400	7.27	5.75	9.80	0.57	0.32
24	400	8.03	6.56	9.80	0.52	0.27
25	400	8.03	6.32	9.64	0.51	0.26
26	400	10.01	7.29	12.04	0.66	0.43
27	400	9.15	6.37	11.50	0.70	0.49
31	400	7.08	5.12	9.26	0.60	0.37
32	400	7.08	5.28	8.59	0.55	0.31
33	400	6.73	5.00	8.57	0.58	0.34
34	400	6.62	5.23	8.08	0.43	0.18
35	400	7.37	5.82	9.00	0.51	0.26
36	400	10.70	6.94	13.29	0.69	0.48
37	400	10.09	6.64	12.46	0.67	0.45
41	400	6.96	4.47	9.23	0.65	0.43
42	400	6.86	5.20	9.08	0.60	0.36
43	400	6.58	3.23	8.80	0.60	0.36
44	400	6.55	5.47	8.15	0.42	0.18
45	400	7.39	6.04	9.02	0.50	0.25
46	400	10.65	7.71	13.32	0.63	0.39
47	400	10.05	6.17	12.80	0.71	0.51

The following results in Table 11 present the general descriptive data on maxillary and mandibular crown height in male and female participants.

Table 11. The descriptive statistics of crown height in mm

Tooth	N	Mean	Minimum	Maximum	SD	VAR
11	400	8.91	6.16	11.52	0.96	0.93
12	400	7.31	4.65	10.30	0.81	0.66
13	400	8.28	5.82	10.93	0.92	0.84
14	400	6.91	4.81	9.86	0.77	0.60
15	400	5.90	3.61	8.67	0.75	0.56
16	400	5.03	3.03	9.76	0.71	0.50
17	400	4.45	2.70	9.48	0.82	0.68
21	400	8.99	6.33	11.80	0.97	0.95
22	400	7.38	4.54	10.43	0.90	0.82
23	400	8.37	6.11	12.13	0.99	0.98
24	400	6.97	4.68	9.69	0.73	0.53
25	400	5.98	3.81	10.00	0.77	0.59
26	400	4.97	2.02	10.25	0.79	0.63
27	400	4.41	2.45	9.76	0.85	0.73
31	400	7.66	5.50	10.09	0.83	0.70
32	400	7.71	5.30	10.47	0.82	0.68
33	400	8.72	5.19	12.46	1.06	1.13
34	400	7.61	3.36	10.18	0.77	0.60
35	400	6.69	4.89	8.62	0.67	0.45
36	400	5.98	4.27	10.56	0.60	0.36
37	400	4.88	3.17	10.21	0.71	0.50
41	400	7.67	5.67	10.52	0.80	0.64
42	400	7.69	5.57	10.17	0.81	0.66
43	400	8.64	5.90	11.96	1.09	1.20
44	400	7.62	5.70	9.80	0.68	0.47
45	400	6.69	4.15	8.82	0.68	0.47
46	400	6.01	4.10	10.53	0.60	0.36
47	400	4.80	2.85	10.72	0.79	0.63

The results in Table 12 are presented as mean, minimum, maximum, standard deviations and variances of tooth size ratios and discrepancies.

Table 12. The descriptive statistics of tooth size ratios (%) and discrepancies (mm)

	N	Mean	Minimum	Maximum	SD	VAR
Anterior ratio	400	79.81	70.50	90.81	2.95	8.74
Overall ratio	400	92.89	81.81	104.96	2.62	6.87
Posterior ratio	400	105.99	91.26	119.87	3.74	14.05
Anterior discrepancy	400	-1.59	-8.58	4.19	1.79	3.21
Overall discrepancy	400	-1.69	-12.90	10.03	2.73	7.45

Table 13 summarizes the means, standard deviations and variances of the occlusal parameters (Little's Incisor Irregularity Index, Overjet and Overbite).

Table 13. The descriptive statistics of occlusal parameters in mm

	N	Mean	Minimum	Maximum	SD	VAR
Upper incisors irregularity	400	4.52	1.1	13.15	1.77	3.15
Lower incisors irregularity	400	2.74	0.7	9.6	1.24	1.54
Overjet	400	3.23	-3.5	12.0	1.92	3.71
Overbite	400	3.60	-6.0	7.8	1.70	2.90

The results of the dental arch measurements are shown in Table 14.

Table 14. The descriptive statistics of dental arch dimensions in mm

	N	Mean	Minimum	Maximum	SD	VAR
Arch width maxilla						
C-C	400	33.89	25.18	40.42	2.28	5.23
P_1-P_1	400	41.00	30.39	47.25	2.78	7.77
P_2-P_2	400	46.35	37.36	53.75	2.96	8.81
M_1-M_1	400	51.24	41.79	61.98	3.21	10.34
Arch width mandible						
C-C	400	26.15	20.97	38.61	2.01	4.05
P_1-P_1	400	34.03	25.52	41.15	2.32	5.41
P_2-P_2	400	39.72	29.80	68.55	3.22	10.38
M_1-M_1	400	44.70	36.45	52.78	2.87	8.27
Arch length						
Arch length maxilla	400	126.82	105.99	143.80	6.91	47.81
Arch length mandible	400	110.31	94.77	128.73	6.01	36.22
Arch perimeter						
Arch perimeter maxilla	400	92.08	71.43	106.91	4.55	20.75
Arch perimeter mandible	400	84.45	59.46	96.43	4.12	17.04
Arch form						
Arch form maxilla	400	40.47	9.33	101.01	15.32	234.84
Arch form mandible	400	48.40	12.80	120.58	19.58	383.54
Arch depth						
Arch depth maxilla	400	29.72	21.13	39.16	2.63	6.92
Arch depth mandible	400	25.24	18.30	36.48	2.48	6.18
Palatal dimensions						
Width of palate	400	34.58	27.0	47.0	2.76	7.63
Length of palate	400	33.22	15.00	40.92	2.99	8.94
Height (depth) of palate	400	12.11	5.5	27.5	2.54	6.47
Palatal height index	400	31.29	18.75	47.77	5.25	27.6

4.2 Parametric and non-parametric sex comparisons

The data below compared the mesiodistal crown widths of the maxillary and mandibular teeth in boys and girls. The analysis showed significant sex differences for all teeth in the maxilla and mandible (p-value = 0.01) (Table 15). Males had larger mesio-distal crown widths than females in all teeth.

Table 15. Sex differences in mesio-distal crown width in mm

Tooth	Female		Male		F	Mean difference	P-values †,‡	Sexual dimorphism (%)
	Mean	SD	Mean	SD				
11‡	8.95^	0.55	9.25	0.56	0.13	-0.30	0.000	3.35
12	6.79	0.54	7.10	0.62	2.84	-0.30	0.000	4.56
13	8.02	0.50	8.44	0.51	0.37	-0.41	0.000	5.23
14	7.09	0.46	7.32	0.44	0.41	-0.23	0.000	3.24
15	6.83	0.47	7.02	0.51	2.32	-0.19	0.000	2.78
16‡	10.01^	0.57	10.33	0.66	0.004	-0.31	0.000	3.19
17‡	9.40^	0.66	9.72	0.81	0.49	-0.31	0.000	3.40
21	8.95	0.56	9.28	0.56	0.02	-0.32	0.000	3.68
22	6.79	0.56	7.02	0.55	0.22	-0.23	0.000	3.38
23	7.95	0.48	8.42	0.54	2.48	-0.46	0.000	5.91
24	7.10	0.47	7.31	0.51	0.62	-0.21	0.000	2.95
25‡	6.75^	0.49	7.00	0.53	3.36	-0.24	0.000	3.70
26‡	10.03^	0.54	10.36	0.68	1.19	-0.32	0.000	3.29
27	9.43	0.53	9.79	0.67	0.27	-0.35	0.000	3.81
31‡	5.76^	0.41	5.97	0.43	0.007	-0.21	0.000	3.64
32	6.25	0.40	6.50	0.41	0.38	-0.25	0.000	4.00
33	7.03	0.46	7.47	0.52	0.28	-0.43	0.000	6.25
34	7.19	0.50	7.44	0.48	0.03	-0.24	0.000	3.49
35	7.15	0.49	7.41	0.49	0.002	-0.25	0.000	3.63
36	10.95	0.68	11.40	0.82	0.06	-0.44	0.000	4.10
37	9.87	0.60	10.29	0.74	0.56	-0.41	0.000	4.25
41	5.74	0.42	5.87	0.40	0.10	-0.12	0.003	2.26
42	6.17	0.39	6.34	0.40	0.01	-0.16	0.000	2.75
43	6.92	0.45	7.40	0.51	1.48	-0.47	0.000	6.93
44	7.18	0.48	7.45	0.51	1.33	-0.26	0.000	3.76
45‡	7.14^	0.51	7.37	0.54	4.64	-0.22	0.000	3.22
46	10.95	0.69	11.43	0.78	0.12	-0.47	0.000	4.38
47	10.08	0.65	10.44	0.72	0.29	-0.36	0.000	3.57

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

The following results in Table 16 provide a comparison of males and females in the bucco-lingual width of the maxillary and mandibular teeth as determined by the Independent Sample T-test and the Mann Whitney U-test. The results reveal significant differences across all teeth, with males having larger bucco-lingual crown widths than females (p-value <0.01).

Table 16. Sex differences in bucco-lingual crown width in mm

Tooth	Female		Male		F	Mean difference	P-values †,‡	Sexual dimorphism (%)
	Mean	SD	Mean	SD				
11	7.19	0.48	7.53	0.60	8.32	-0.33	0.000	4.72
12‡	6.34^	0.54	6.76	0.60	0.31	-0.42	0.000	6.62
13	7.91	0.64	8.37	0.78	6.34	-0.46	0.000	5.81
14	9.19	0.57	9.55	0.55	0.49	-0.36	0.000	3.91
15	9.32	0.66	9.75	0.64	0.25	-0.43	0.000	4.61
16	10.75	0.66	11.19	0.66	0.09	-0.44	0.000	4.09
17	10.36	0.72	10.87	0.84	5.65	-0.51	0.000	4.92
21	7.21	0.51	7.51	0.61	3.67	-0.29	0.000	4.16
22	6.39	0.50	6.73	0.58	0.42	-0.34	0.000	5.32
23	8.00	0.57	8.44	0.73	15.36	-0.44	0.000	5.50
24	9.16	0.56	9.51	0.57	0.11	-0.35	0.000	3.82
25	9.27	0.59	9.73	0.58	0.07	-0.45	0.000	4.96
26	10.79	0.60	11.19	0.65	1.58	-0.41	0.000	3.70
27	10.35	0.69	10.85	0.71	0.11	-0.50	0.000	4.83
31	6.11	0.46	6.37	0.52	1.86	-0.26	0.000	4.25
32	6.44	0.44	6.62	0.48	2.53	-0.18	0.000	2.79
33	7.32	0.49	7.71	0.80	43.09	-0.38	0.000	5.32
34‡	7.85^	0.50	8.21	0.62	12.04	-0.36	0.000	4.58
35‡	8.48^	0.54	8.82	0.66	3.27	-0.34	0.000	4.00
36‡	10.42^	0.55	10.70	0.88	3.39	-0.28	0.000	2.68
37	9.91	0.65	10.20	0.68	1.85	-0.29	0.000	2.92
41‡	6.12^	0.47	6.35	0.54	2.51	-0.23	0.000	3.75
42‡	6.37^	0.43	6.57	0.56	2.83	-0.20	0.000	3.13
43	7.27	0.51	7.66	0.79	38.44	-0.38	0.000	5.36
44	7.90	0.55	8.28	0.58	2.32	-0.38	0.000	4.43
45	8.54	0.51	8.91	0.63	9.36	-0.37	0.000	4.33
46‡	10.45^	0.56	10.78	0.56	1.72	-0.33	0.000	3.15
47	9.85	0.63	10.20	0.71	4.98	-0.35	0.000	3.55

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

From the results in Table 17 it may be seen that there are significant differences in diagonal crown widths MBDL between males and females for all teeth. The results show that males had higher values than females.

Table 17. Sex differences in diagonal crown width MBDL in mm

Tooth	Female		Male		F	Mean difference	P-values †,‡	Sexual dimorphism (%)
	Mean	SD	Mean	SD				
11	9.02	0.59	9.51	0.58	0.19	-0.50	0.000	5.43
12	7.17	0.64	7.63	0.61	1.04	-0.46	0.000	6.41
13‡	7.45^	0.54	7.85	0.61	3.35	-0.41	0.000	5.36
14	7.47	0.45	7.76	0.46	0.05	-0.29	0.000	3.88
15‡	7.63^	0.51	7.92	0.49	0.12	-0.29	0.000	3.80
16	11.34	0.63	11.71	0.62	0.05	-0.36	0.000	3.26
17‡	10.12^	0.93	10.60	1.02	1.11	-0.47	0.000	4.74
21	9.02	0.58	9.50	0.59	0.07	-0.47	0.000	5.32
22‡	7.23^	0.66	7.62	0.63	1.77	-0.38	0.000	5.39
23	7.41	0.56	7.79	0.69	8.03	-0.38	0.000	5.12
24	7.33	0.45	7.52	0.47	0.83	-0.19	0.000	2.59
25	7.42	0.46	7.64	0.48	0.03	-0.21	0.000	2.96
26‡	11.39^	0.62	11.76	0.63	0.11	-0.37	0.000	3.24
27‡	10.10^	0.97	10.51	1.03	1.09	-0.41	0.000	4.05
31	6.92	0.74	7.22	0.66	2.61	-0.30	0.000	4.33
32	7.03	0.65	7.36	0.61	0.31	-0.33	0.000	4.69
33	7.19	0.71	7.62	0.58	3.96	-0.43	0.000	5.98
34	6.94	0.49	7.17	0.49	0.08	-0.23	0.000	3.31
35‡	7.35	0.56	7.57^	0.50	2.69	-0.22	0.001	2.99
36‡	10.52	0.57	10.83^	0.70	0.27	-0.31	0.000	2.94
37‡	9.90	0.65	10.27^	0.72	0.003	-0.36	0.000	3.73
41‡	6.96	0.75	7.22^	0.68	2.21	-0.26	0.001	3.73
42	7.20	0.70	7.43	0.64	1.09	-0.23	0.001	3.19
43	7.35	0.70	7.71	0.62	0.96	-0.36	0.000	4.89
44‡	6.86	0.52	7.07^	0.48	5.54	-0.21	0.000	3.06
45	7.21	9.55	7.37	0.48	3.00	-0.16	0.002	2.21
46	10.69	0.56	10.99	0.55	0.06	-0.30	0.000	2.80
47	9.94	0.62	10.38	0.66	0.07	-0.44	0.000	4.42

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

Regarding the diagonal crown width, MLDB in both jaws, as shown in Table 18, the independent sample t-test and the Mann Whitney U-test revealed significant differences between males and females for all teeth, with males having higher diagonal crown width MLDB values than females.

Table 18. Sex differences in diagonal crown width MLDB in mm

Tooth	Female		Male		F	Mean difference	P-values †,‡	Sexual dimorphism (%)
	Mean	SD	Mean	SD				
11	8.40	0.58	8.72	0.63	1.35	-0.31	0.000	3.80
12	6.77	0.62	7.02	0.65	0.57	-0.25	0.000	3.69
13	7.21	0.49	7.49	0.62	9.12	-0.28	0.000	3.88
14	7.81	0.44	7.98	0.47	0.24	-0.17	0.000	2.17
15	7.72	0.43	7.97	0.49	3.48	-0.25	0.000	3.23
16‡	9.78^	0.68	10.12	0.71	3.51	-0.34	0.000	3.47
17	8.86	0.71	9.16	0.73	0.04	-0.30	0.000	3.38
21‡	8.23^	0.60	8.56	0.64	0.81	-0.33	0.000	4.00
22‡	6.65^	0.57	6.90	0.64	3.61	-0.25	0.000	3.75
23	7.14	0.48	7.43	0.62	8.86	-0.28	0.000	4.48
24	7.92	0.49	8.17	0.53	0.89	-0.25	0.000	3.15
25	7.87	0.46	8.22	0.51	2.12	-0.34	0.000	4.44
26	9.85	0.61	10.21	0.67	2.34	-0.36	0.000	3.65
27	8.97	0.67	9.38	0.68	0.42	-0.40	0.000	4.57
31	7.00	0.61	7.18	0.60	0.00	-0.18	0.003	2.57
32	7.01	0.52	7.17	0.58	2.55	-0.16	0.004	2.28
33	6.63	0.50	6.87	0.65	11.40	-0.25	0.000	3.61
34‡	6.55^	0.43	6.70	0.42	0.00	-0.15	0.000	2.29
35	7.29	0.47	7.47	0.54	2.38	-0.18	0.000	2.46
36‡	10.51^	0.66	10.94	0.66	0.00	-0.43	0.000	4.09
37	9.89	0.63	10.33	0.66	0.71	-0.45	0.000	4.44
41‡	6.86^	0.64	7.08	0.66	1.15	-0.22	0.000	3.20
42‡	6.76^	0.53	6.99	0.66	7.39	-0.22	0.001	3.40
43‡	6.47^	0.51	6.73	0.68	8.18	-0.26	0.000	4.01
44	6.47	0.40	6.65	0.44	0.99	-0.17	0.000	2.78
45	7.31	0.44	7.49	0.55	7.60	-0.17	0.001	2.46
46	10.47	0.61	10.88	0.58	0.36	-0.40	0.000	3.91
47	9.81	0.67	10.35	0.66	0.36	-0.54	0.000	5.50

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

The comparative analyses between males and females for crown height are shown in Table 19. Accordingly, males and females differed in relation to most teeth, with males generally having higher crown height than females. In contrast, teeth 27,31,32,36,37,41,42,46,47 showed no significant differences.

Table 19. Sex differences in crown height in mm

Tooth	Female		Male		F	Mean difference	P-values †,‡
	Mean	SD	Mean	SD			
11	8.75	0.91	9.11	0.99	1.60	-0.35	0.000
12‡	7.19^	0.78	7.47	0.82	0.28	-0.29	0.001
13	8.11	0.83	8.48	0.99	3.37	-0.37	0.000
14‡	6.75^	0.70	7.11	0.82	3.93	-0.36	0.000
15	5.73	0.72	6.11	0.74	0.00	-0.38	0.000
16‡	4.92^	0.57	5.18	0.83	8.59	-0.25	0.000
17	4.36	0.74	4.57	0.90	2.36	-0.21	0.014
21	8.89	0.91	9.12	1.04	3.64	-0.23	0.020
22	7.27	0.90	7.52	0.90	0.00	-0.25	0.007
23	8.20	0.87	8.58	1.08	7.52	-0.39	0.000
24	6.81	0.64	7.17	0.79	6.37	-0.36	0.000
25‡	5.81^	0.72	6.17	0.78	3.91	-0.35	0.000
26‡	4.86^	0.59	5.10	0.96	14.02	-0.24	0.005
27‡	4.34^	0.81	4.49	0.91	1.05	-0.15	0.061
31	7.60	0.80	7.75	0.87	2.30	-0.14	0.095
32	7.64	0.83	7.80	0.82	0.04	-0.16	0.051
33‡	8.46^	0.90	9.05	1.16	16.01	-0.59	0.000
34	7.37	0.64	7.88	0.83	5.293	-0.50	0.000
35	6.53	0.59	6.88	0.71	6.39	-0.35	0.000
36	5.94	0.49	6.04	0.71	10.48	-0.09	0.131
37	4.85	0.61	4.93	0.81	5.53	-0.08	0.279
41	7.62	0.77	7.75	0.84	2.89	-0.13	0.099
42	7.63	0.79	7.77	0.85	2.47	-0.15	0.073
43‡	8.38^	0.89	8.96	1.23	26.91	-0.58	0.000
44	7.40	0.61	7.88	0.68	2.91	-0.49	0.000
45	6.53	0.60	6.88	0.74	10.58	-0.35	0.000
46	5.98	0.51	6.06	0.70	5.84	-0.08	0.223
47‡	4.77^	0.72	4.84	0.87	1.35	-0.07	0.577

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

Table 20 compares males and females in terms of tooth size ratios and discrepancies. The Independent Sample T-test and the Mann Whitney U-test were used to confirm this comparison and to look for changes. Males and females showed no statistically significant differences (p-value > 0.05).

Table 20. Sex differences in tooth size discrepancies

	Female		Male		F	Mean difference	P-values†,‡
	Mean	SD	Mean	SD			
Anterior ratio ‡	79.83^	3.06	79.80^	2.83	0.28	0.04	0.71
Overall ratio	92.84	2.73	92.97	2.50	0.39	-0.13	0.63
Posterior ratio	105.79	3.76	106.23	3.73	0.06	-0.44	0.24
Anterior discrepancy	-1.55	1.78	-1.65	1.80	0.13	0.09	0.60
Overall discrepancy	-1.63	2.77	-1.77	2.68	0.02	0.14	0.60

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

Regarding the occlusal parameters, according to the results shown in Table 21, there was a significant sex difference in the index of maxillary and mandibular incisor irregularity, with males having higher dimensions than females, p-value = 0.009 and 0.007. In contrast, although males had larger average values than females, no significant sex differences were found for overjet and overbite (p-value > 0.05, in both cases) (Table 21).

Table 21. Sex differences in the incisal irregularity index, overjet and overbite

	Female		Male		F	Mean difference	P-value‡
	Mean	SD	Mean	SD			
Maxilla irregularity index	4.28	1.58	4.81	1.95	4.27	-0.52	**0.009***
Mandible irregularity index	2.56	1.03	2.96	1.43	9.96	-0.40	**0.006***
Overjet	3.03	1.81	3.47	2.02	3.36	-0.44	0.118
Overbite	3.51	1.82	3.72	1.54	0.001	-0.21	0.446

** statistically significant at 0.05; ‡ Mann Whitney U-test*

Table 22 shows the results of sex differences in dental arch dimensions, performed by the Independent Sample T-test and Mann Whitney U-tests. The mean, standard deviation, mean difference, and the p-value were reported. For all dimensions, analysis indicated statistically significant sex differences ($p<0.05$), except for mandibular arch form and palatal height index. The arch dimensions were generally larger in males, with the exception of maxillary arch form, which was larger in females.

Table 22. Sex differences in dental arch dimensions

Dental arch dimensions		Mean		SD		F	Mean difference	P-value †, ‡
		Male	Female	Male	Female			
Arch width maxillae	C-C	34.95	32.99	2.00	2.12	0.03	1.96	0.000
	P_1-P_1	42.17	40.01	2.61	2.53	0.25	2.16	0.000
	P_2-P_2	47.61	45.27	2.87	2.60	1.19	2.34	0.000
	M_1-M_1	52.78	49.93	2.96	2.82	0.03	2.85	0.000
Arch width mandible	C-C‡	26.72^	25.56	1.99	2.46	0.09	1.16	0.000
	P_1-P_1	34.94	33.25	2.06	2.25	1.25	1.69	0.000
	P_2-P_2	40.85	38.76	2.67	3.33	0.05	2.09	0.000
	M_1-M_1	45.87	43.57	3.69	2.60	0.48	2.30	0.000
Arch length	Arch length maxilla	130.42	123.76	6.30	5.86	0.03	6.66	0.000
	Arch length mandible	113.23	107.83	5.25	5.50	0.18	5.40	0.000
Arch perimeter	Arch perimeter maxilla	93.95	90.48	4.29	4.15	0.005	3.47	0.000
	Arch perimeter mandible	86.22	82.94	4.04	3.56	0.001	3.28	0.000
Arch form	Arch form maxilla‡	38.88^	41.83	17.36	13.22	12.46	-2.95	0.004
	Arch form mandible‡	49.98^	47.06	23.05	15.97	20.44	2.92	0.901
Arch depth	Arch depth maxilla	30.45	29.10	2.60	2.50	0.01	1.35	0.000
	Arch depth mandible	25.62	24.91	2.43	2.48	0.52	0.71	0.004
Palatal dimensions	Width of palate ‡	35.63^	33.69	2.52	2.64	0.01	1.94	0.000
	Length of palate	33.83	32.71	2.77	3.07	1.01	1.12	0.000
	Height (depth) of palate‡	12.53^	11.75	2.61	2.43	2.83	0.78	0.002
	Palatal height index	31.32	31.25	5.59	4.97	1.72	-0.06	0.901

†Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

4.3 Parametric and non-parametric comparisons of malocclusion classes

To analyze the relationship between the three classes of malocclusions and the mesio-distal crown width of maxillary and mandibular teeth for variables with normal data distribution, the ANOVA test was used, and the Kruskal-Wallis test for variables with non-normal data distribution. Table 23 presents the mesio-distal crown widths of maxillary and mandibular teeth for each of the three classes of malocclusion. The results show significant differences between classes and mesiodistal widths of maxillary teeth (12,13,14,22,23,24) and mandibular teeth (33,34,36) by ANOVA test. Class I had higher values followed by classes II and III (p-value <0.005).

Table 24 presents the mean and standard deviation of the buccolingual crown widths of the maxillary and mandibular teeth in three malocclusion classes (class I, II, and III). The p-values for ANOVA and Kruskal-Wallis tests are also provided, to indicate the significance of the differences between the malocclusion classes.

For most teeth, there were no significant differences in BL crown width measurements between the malocclusion classes, as indicated by non-significant p-values. However, there were a few exceptions. ANOVA test found significant differences in the mandibular teeth 31, 32, and 44 (p=0.009, p=0.044 and p=0.040, respectively), with class III having higher values for teeth 31,32 than classes II and I, and class I having higher values for tooth 44 than classes II and III.

The following analysis in Table 25 presents the results of comparison of the classes of diagonal crown width MBDL (maxilla and mandible) performed by the ANOVA and Kruskal-Wallis tests. According to the findings, a significant difference was only found in tooth 16 by the ANOVA test. Class I malocclusion had the highest mean value (11.56 mm), p-value = 0.028.

The results of comparison of the classes and the diagonal crown width MLDB (maxillary and mandibular teeth) are shown in Table 26. Significant differences for teeth 14, 15, 31, 32, 33, 41, 42 and 43 were observed. Specifically, class I malocclusions had the highest values for teeth 14,15; whereas Class III malocclusions had the highest values for teeth 31,32,33,41,42,43.

The findings of the comparison tests of ANOVA and Kruskal-Wallis between the malocclusion classes and the crown height of maxillary and mandibular teeth are presented in Table 27. Significant differences in crown height between malocclusion classes were found in teeth 22, 23, 24, 31, 32, 34, 35, 36, 37, 41, 42, 45 by the ANOVA test, while significant differences were found in teeth 14, 25 and 47 by the Kruskal-Wallis test.

Table 23. Mesio-distal crown width in different malocclusion groups

Class	I		II		III		P-value
Tooth	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	*†* ‡
11‡	9.15	0.55	9.04	0.57	8.95	0.74	0.087
12	7.00	0.62	6.88	0.55	6.71	0.70	**0.042***
13	8.27	0.52	8.18	0.52	7.93	0.81	**0.011***
14	7.26	0.43	7.14	0.49	7.04	0.53	**0.013***
15	6.95	0.47	6.90	0.53	6.83	0.49	0.492
16‡	10.16	0.69	10.17	0.54	10.04	0.72	0.795
17‡	9.56	0.71	9.54	0.70	9.42	1.29	0.794
21	9.15	0.55	9.05	0.59	9.06	0.79	0.248
22	6.97	0.55	6.82	0.56	6.71	0.77	**0.017***
23	8.23	0.54	8.15	0.54	7.73	0.72	**0.000***
24	7.28	0.46	7.11	0.52	7.05	0.57	**0.002***
25‡	6.92	0.50	6.81	0.54	6.72	0.53	0.064
26‡	10.24	0.70	10.15	0.53	9.96	0.61	0.063
27	9.64	0.67	9.56	0.54	9.48	0.71	0.333
31‡	5.86	0.44	5.86	0.42	5.79	0.48	0.680
32	6.38	0.42	6.36	0.40	6.20	0.53	0.169
33	7.28	0.54	7.22	0.50	6.88	0.61	**0.004***
34	7.36	0.50	7.26	0.49	7.10	0.64	**0.032***
35	7.30	0.53	7.27	0.49	7.06	0.49	0.110
36	11.26	0.82	11.05	0.70	10.96	0.84	**0.016***
37	10.08	0.74	10.05	0.63	10.08	0.83	0.889
41	5.81	0.40	5.77	0.38	5.93	0.71	0.200
42	6.25	0.40	6.26	0.41	6.12	0.45	0.297
43	7.18	0.54	7.12	0.50	6.96	0.64	0.147
44	7.36	0.48	7.26	0.53	7.14	0.60	0.060
45‡	7.25	0.51	7.26	0.58	7.07	0.47	0.340
46	11.24	0.80	11.10	0.71	10.97	0.90	0.106
47	10.31	0.72	10.17	0.69	10.27	0.62	0.161

**, ** p-value < 0.01 & <0.05; † ANOVA test; ‡ Kruskal-Wallis test*

Table 24. Bucco-lingual crown width in different malocclusion groups

Class	I		II		III		P-value
Tooth	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**†, ‡**
11	7.38	0.51	7.31	0.61	7.26	0.69	0.331
12‡	6.56	0.54	6.51	0.65	6.59	0.79	0.639
13	8.20	0.68	8.04	0.80	8.02	0.79	0.082
14	9.39	0.58	9.32	0.61	9.29	0.55	0.404
15	9.55	0.66	9.48	0.73	9.46	0.60	0.602
16	10.93	0.70	10.98	0.69	10.99	0.64	0.791
17	10.59	0.84	10.59	0.80	10.72	0.76	0.773
21	7.39	0.53	7.31	0.63	7.26	0.62	0.300
22	6.57	0.55	6.51	0.56	6.60	0.79	0.484
23	8.26	0.63	8.11	0.72	8.28	0.82	0.073
24	9.37	0.57	9.27	0.62	9.25	0.50	0.192
25	9.52	0.62	9.46	0.65	9.30	0.55	0.252
26	10.96	0.68	10.99	0.64	11.02	0.52	0.907
27	10.59	0.75	10.55	0.73	10.74	0.73	0.510
31	6.24	0.48	6.18	0.46	6.53	0.87	**0.009***
32	6.54	0.46	6.48	0.43	6.74	0.68	**0.044***
33	7.52	0.66	7.45	0.67	7.68	0.89	0.237
34‡	8.07	0.61	7.96	0.52	7.86	0.78	0.248
35‡	8.68	0.59	8.59	0.66	8.48	0.64	0.462
36‡	10.58	0.58	10.54	0.88	10.36	0.79	0.724
37	10.09	0.63	9.99	0.72	10.01	0.80	0.339
41‡	6.23	0.46	6.19	0.50	6.54	0.94	0.281
42‡	6.46	0.47	6.43	0.45	6.75	0.95	0.234
43	7.46	0.66	7.41	0.66	7.61	1.00	0.420
44	8.14	0.60	8.01	0.56	7.92	0.72	**0.040***
45	8.74	0.62	8.69	0.54	8.51	0.71	0.207
46‡	10.61	0.58	10.61	0.57	10.45	0.76	0.996
47	10.04	0.65	9.97	0.72	10.02	0.78	0.570

, statistically significant at 0.05; † ANOVA test; ‡ Kruskal-Wallis test*

Table 25. Diagonal crown width MBDL in different malocclusion groups

Class	I		II		III		P-value
Tooth	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	† ‡
11	9.25	0.62	9.25	0.64	9.11	0.68	0.599
12	7.35	0.64	7.41	0.69	7.31	0.79	0.610
13 ‡	7.68	0.61	7.59	0.60	7.57	0.67	0.242
14	7.64	0.49	7.57	0.45	7.54	0.45	0.229
15 ‡	7.76	0.51	7.76	0.54	7.74	0.44	0.944
16	11.56	0.65	11.49	0.60	11.17	0.87	**0.028***
17 ‡	10.35	1.03	10.32	0.95	10.40	1.14	0.931
21	9.27	0.59	9.20	0.68	9.23	0.58	0.583
22 ‡	7.41	0.67	7.41	0.66	7.48	0.78	0.964
23	7.63	0.63	7.53	0.68	7.48	0.65	0.253
24	7.46	0.45	7.35	0.49	7.38	0.45	0.070
25	7.55	0.47	7.49	0.50	7.51	0.45	0.469
26 ‡	11.60	0.65	11.55	0.62	11.23	0.80	0.101
27 ‡	10.28	1.04	10.29	1.00	10.38	0.96	0.877
31	7.02	0.68	7.07	0.70	7.39	1.04	0.062
32	7.14	0.65	7.20	0.63	7.42	0.78	0.149
33	7.39	0.66	7.38	0.68	7.51	0.83	0.702
34	7.07	0.49	7.03	0.52	6.95	0.46	0.462
35 ‡	7.50	0.55	7.41	0.53	7.29	0.45	0.085
36 ‡	10.69	0.69	10.65	0.54	10.54	1.07	0.694
37 ‡	10.12	0.67	10.00	0.71	10.11	1.02	0.100
41 ‡	7.05	0.67	7.06	0.75	7.48	0.91	0.072
42	7.29	0.66	7.30	0.66	7.55	0.97	0.217
43	7.52	0.65	7.49	0.69	7.70	0.94	0.410
44 ‡	6.98	0.53	6.93	0.50	6.99	0.43	0.442
45	7.31	0.52	7.24	0.54	7.31	0.46	0.436
46	10.83	0.59	10.80	0.55	10.95	0.58	0.502
47	10.19	0.63	10.07	0.72	10.23	0.79	0.200

*,** *statistically significant at 0.05; † ANOVA test; ‡ Kruskal-Wallis test*

Table 26. Diagonal crown width MLDB in different malocclusion groups

Class	I		II		III		P-value †
Tooth	Mean	SD	Mean	SD	Mean	SD	‡
11	8.55	0.60	8.55	0.65	8.53	0.70	0.987
12	6.89	0.64	6.91	0.63	6.66	0.80	0.224
13	7.37	0.54	7.30	0.59	7.36	0.63	0.549
14	7.95	0.46	7.79	0.46	7.97	0.41	**0.001***
15	7.89	0.48	7.77	0.45	7.83	0.53	**0.047***
16 ‡	9.99	0.76	9.90	0.67	9.78	0.67	0.280
17	8.98	0.73	9.03	0.75	8.98	0.65	0.738
21 ‡	8.38	0.60	8.39	0.66	8.37	0.86	0.862
22 ‡	6.73	0.57	6.80	0.64	6.77	0.86	0.691
23	7.31	0.50	7.22	0.62	7.30	0.77	0.271
24	8.08	0.50	7.96	0.55	8.07	0.48	0.068
25	8.07	0.53	7.99	0.49	7.98	0.55	0.270
26	10.04	0.71	10.00	0.59	9.95	0.72	0.742
27	9.15	0.73	9.19	0.66	9.04	0.78	0.619
31	7.11	0.58	7.00	0.60	7.42	0.78	**0.006***
32	7.14	0.55	6.97	0.54	7.36	0.62	**0.001***
33	6.78	0.54	6.64	0.61	7.12	0.67	**0.000***
34 ‡	6.65	0.42	6.60	0.44	6.48	0.43	0.239
35	7.40	0.50	7.36	0.53	7.25	0.53	0.432
36 ‡	10.78	0.63	10.64	0.69	10.57	1.11	0.449
37	10.12	0.68	10.08	0.63	9.98	0.97	0.604
41 ‡	6.96	0.63	6.91	0.64	7.39	0.86	**0.010****
42 ‡	6.88	0.57	6.80	0.61	7.22	0.78	**0.004****
43 ‡	6.59	0.62	6.54	0.57	6.94	0.69	**0.041****
44	6.58	0.44	6.51	0.40	6.65	0.43	0.185
45	7.42	0.50	7.37	0.51	7.34	0.51	0.623
46	10.71	0.66	10.59	0.57	10.63	0.77	0.179
47	10.07	0.75	10.03	0.67	10.13	0.79	0.799

*,** *statistically significant at 0.05; † ANOVA test; ‡ Kruskal-Wallis test*

Table 27. Crown height in different malocclusion groups

Class	I		II		III		P-value
Tooth	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	† ‡
11	8.95	0.96	8.85	0.95	9.06	1.11	0.447
12‡	7.35	0.77	7.28	0.85	7.24	0.95	0.448
13	8.33	0.88	8.18	0.96	8.56	0.97	0.089
14‡	6.97	0.73	6.82	0.78	7.19	1.04	**0.041****
15	5.94	0.70	5.83	0.80	6.12	0.85	0.145
16‡	5.02	0.69	5.02	0.73	5.33	0.75	0.094
17	4.47	0.79	4.40	0.83	4.80	1.03	0.100
21	9.04	0.94	8.91	1.01	9.22	1.02	0.234
22	7.45	0.83	7.25	0.91	7.80	1.31	**0.009***
23	8.45	0.91	8.24	1.01	8.73	1.40	**0.028***
24	7.07	0.69	6.81	0.74	7.22	0.79	**0.000***
25‡	6.07	0.04	5.84	0.79	6.02	0.96	**0.015****
26‡	4.96	0.75	4.96	0.83	5.15	0.86	0.664
27‡	4.46	0.80	4.34	0.90	4.54	1.02	0.183
31	7.75	0.82	7.53	0.85	7.97	0.75	**0.009***
32	7.77	0.76	7.58	0.88	8.14	0.93	**0.004***
33‡	8.76	1.00	8.64	1.07	9.12	1.55	0.385
34	7.69	0.69	7.47	0.80	7.84	1.13	**0.010***
35	6.76	0.65	6.58	0.66	6.89	0.86	**0.015***
36	6.08	0.57	5.86	0.61	6.06	0.72	**0.001***
37	4.98	0.71	4.76	0.68	4.93	0.81	**0.012***
41	7.73	0.80	7.56	0.77	8.09	0.85	**0.005***
42	7.75	0.77	7.57	0.82	8.09	1.06	**0.008***
43‡	8.68	1.12	8.59	1.00	8.79	1.56	0.867
44	7.69	0.68	7.54	0.68	7.61	0.76	0.134
45	6.78	0.68	6.58	0.65	6.77	0.92	**0.018***
46	6.08	0.59	5.94	0.59	5.99	0.80	0.095
47‡	4.90	0.77	4.67	0.79	4.97	0.91	**0.030****

*,** *statistically significant at 0.05; † ANOVA test; ‡ Kruskal-Wallis test*

The results of the Kruskall-Wallis test showed statistically significant differences in the anterior ratio and anterior discrepancy between the different malocclusion classes ($p<0.05$), as presented in Table 28. Additionally, the ANOVA test revealed significant sex differences between malocclusion groups, with females in Class III demonstrating higher average values for anterior ratio (80.92) and anterior discrepancy (-2.02), as well as p-values of 0.024 and 0.022, respectively (also presented in Table 28). These findings suggest that sex may also play a role in these differences.

Table 28. The mean, standard deviation (SD), Kruskal-Wallis, and analysis of variance (ANOVA) tests for the anterior, posterior, and overall ratios, and anterior and overall discrepancies in different malocclusion groups

	Anterior ratio		**Overall ratio**		**Posterior ratio**		**Anterior discrepancy**		**Overall discrepancy**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Class I	79.37	2.69	92.69	2.27	106.02	3.22	-1.32	1.63	-1.56	2.34
Class II	80.31	2.87	93.12	2.77	105.96	4.22	-1.92	1.79	-1.84	2.94
Class III	80.41	4.90	93.21	4.20	105.97	4.78	-1.81	2.75	-1.87	4.27
P-value ‡	**0.012****		0.232		0.922		**0.011****		0.412	
FEMALES	**Anterior ratio**		**Overall ratio**		**Posterior ratio**		**Anterior discrepancy**		**Overall discrepancy**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**STD**	**Mean**	**SD**	**Mean**	**SD**
Class I	79.30	2.76	92.45	2.23	105.59	3.11	-1.22	1.61	-1.32	2.22
Class II	80.30	2.71	93.21	2.81	106.01	4.24	-1.87	1.62	-1.94	2.94
Class III	80.92	5.69	93.45	4.72	105.89	5.12	-2.02	3.18	-2.02	4.76
P-value *†*	**0.024***		0.093		0.735		**0.022***		0.253	
MALES	**Anterior ratio**		**Overall ratio**		**Posterior ratio**		**Anterior discrepancy**		**Overall discrepancy**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Class I	79.44	2.62	92.95	2.29	106.48	3.28	-1.41	1.65	-1.82	2.45
Class II	80.33	3.08	93.01	2.73	105.91	4.23	-1.99	1.98	-1.73	2.96
Class III	79.31	2.50	92.69	3.05	106.12	4.35	-1.35	1.60	-1.53	3.29
P-value[1]	0.108		0.947		0.607		0.100		0.949	

,Statistically significant at 0.05; SD-Standard deviation; † ANOVA test; ‡ Kruskal-Wallis test*

On the other hand, the results of Dunn's post-hoc test showed that there were significant differences in the anterior ratio between classes I and II ($p<0.05$). However, there were no significant differences between classes I and III or between classes III and II. In addition, significant differences in the anterior discrepancy were observed between classes II and I ($p<0.05$), but not between classes II and III, or between classes III and I. These findings are presented in Table 29, which provides multiple comparisons between malocclusion classes in anterior ratio and anterior discrepancy. The adjusted significance values (adj.Sig.a) for each comparison were calculated using the Bonferroni correction for multiple tests.

Table 29. Multiple comparisons among malocclusion classes in anterior ratio and anterior discrepancy by post-hoc Dunn's test.

Pairwise Comparisons of Classes						
	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	**Adj. Sig.[a]**
Anterior ratio	**I-III**	-30.069	25.896	-1.161	.246	.737
	I-II	-34.791	11.982	-2.904	.004	**.012**
	III-II	4.722	26.231	.180	.857	1.000
	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	**Adj. Sig.[a]**
Anterior discrepancy	**II-III**	-5.615	26.231	-.214	.831	1.000
	II-I	35.312	11.982	2.947	.003	**.010**
	III-I	29.697	25.896	1.147	.251	.754

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

To illustrate tooth size discrepancies, Table 30 and Table 31 demonstrate the mean values for anterior and overall tooth size discrepancies, respectively. Our findings indicate that the frequency of a significant disparity (more than 2 SD) in the anterior ratio was 41.37 percent. On the other hand, the incidence of a significant overall ratio discrepancy in the current study was 23.79 percent. These results suggest that a substantial proportion of individuals in our sample had significant TSDs, particularly in the anterior ratio.

Table 30. Anterior tooth size discrepancy compared to Bolton's norms

Anterior TSDs	Class I	Class II	Class III
<2SD (%)	1.41	1.2	9.09
2SD (%)	6.6	1.8	4.54
1SD (%)	11.79	9.63	13.63
Mean ((%))	0.47	0	0
1SD (%)	19.81	17.46	0
2SD (%)	26.41	24.69	27.27
>2SD (%)	33.49	45.18	45.45

Table 31. Overall tooth size discrepancy compared to Bolton's norms

Overall TSDs	Class I	Class II	Class III
<2SD (%)	1.88	1.8	9.09
2SD (%)	3.3	7.83	9.09
1SD (%)	20.28	11.44	13.63
Mean ((%))	2.35	1.2	4.54
1SD (%)	28.77	29.51	9.09
2SD (%)	30.66	25.9	18.18
>2SD (%)	12.73	22.28	36.36

Table 32 presents a comparison of occlusal parameters (incisal irregularity index, overjet and overbite) among the different classes of malocclusion using the Kruskal-Wallis test. According to the findings, a significant difference was found in upper incisor irregularity, with class III malocclusions having the highest mean and a p-value of 0.024. However, no significant difference was found for lower incisor irregularity (p-value>0.05). Furthermore, significant differences were found in overjet and overbite (p-value=0.005, for both), with class II malocclusion having the highest average for overjet (4.35) and for overbite (4.18), respectively.

Table 33 was analyzed to determine the differences between malocclusion classes in terms of arch width, arch length, arch perimeter, arch form, arch depth, palatal dimensions, and palatal height index. Both ANOVA and Kruskal-Wallis tests were applied for the analysis.

The results of the ANOVA test indicated that there were significant differences between malocclusion classes in terms of maxillary arch widths, maxillary arch length, maxillary arch perimeter, maxillary arch depth, and palatal length. Specifically, class I malocclusions showed the highest values, followed by classes II and III (p-value<0.05).

Table 32. Occlusal parameters in different malocclusion classes

Parameter	**I**		**II**		**III**		**F**	**P-value ‡**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**		
Upper incisors irregularity	4.27	1.51	4.76	1.96	5.26	2.26	5.70	**0.024***
Lower incisors irregularity	2.59	1.04	2.90	1.42	3.13	1.42	4.03	0.110
Overjet	2.66	0.91	4.35	2.10	0.23	2.19	94.19	0.0005*
Overbite	3.54	1.14	4.18	1.31	-0.19	3.26	94.74	0.0005*

* *statistically significant at 0.05*; ‡ Kruskal-Wallis test

The results of the Kruskal-Wallis test showed a significant difference between malocclusion classes in mandibular arch form, with class III malocclusion having the highest value (30.36), and p-value = 0.026. In terms of palatal width, class I malocclusion had the highest average value (35.17), and a p-value of 0.000. For palatal height (depth), class III malocclusion had the highest average value (13.18) and p-value = 0.010.

In the comparison of the palatal height index among the different malocclusion classes, the analysis found that the average value was the highest for class III, followed by classes II and I. However, the F-test did not reveal any significant differences between the classes in terms of palatal height index, with a calculated F value of 2.02 and a p-value of 0.133, which indicates that the p-value is greater than 0.05.

Table 33. Dental arch dimensions in different malocclusion classes

Dental arch dimensions		**Mean**			**SD**			**F**	**P-value† ,‡**
		Class I	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**		
Arch width maxilla	C-C	34.22	33.45	34.09	2.149	2.39	2.32	5.46	**0.005***
	P_1-P_1	41.59	40.24	41.19	2.62	2.780	3.078	11.53	**0.000***
	P_2-P_2	47.05	45.39	46.76	2.79	2.92	3.09	15.83	**0.000***
	M_1-M_1	51.96	50.25	51.78	3.13	3.10	3.00	14.33	**0.000***
Arch width mandible	C-C ‡	26.07	26.03	26.66	1.68	2.96	2.31	0.71	**0.264**
	P_1-P_1	34.12	33.89	34.23	2.08	2.50	3.08	0.53	**0.587**
	P_2-P_2	39.71	39.84	38.98	2.67	3.71	4.06	0.70	**0.493**
	M_1-M_1	44.50	44.82	44.40	3.69	2.82	3.60	0.45	**0.632**
Arch length	Arch length maxilla	128.46	124.58	127.88	6.42	6.99	6.38	16.05	**0.000***
	Arch length mandible	110.29	110.44	109.54	5.86	6.08	7.20	0.22	**0.802**
Arch perimeter	Arch perimeter maxilla	92.70	91.37	91.42	4.09	5.05	4.07	4.32	**0.014***
	Arch perimeter mandible	84.85	84.01	83.86	3.94	4.28	4.37	2.20	**0.112**
Arch form	Arch form maxilla ‡	40.57	39.45	47.24	14.37	16.03	17.61	2.53	0.124
	Arch form mandible ‡	45.58	50.46	60.06	16.65	20.81	28.97	7.23	**0.031***
Arch depth	Arch depth maxilla	29.98	29.31	30.36	2.23	3.07	2.15	3.68	**0.026***
	Arch depth mandible	25.47	25.01	24.74	2.55	2.36	2.65	2.04	**0.131**
Palatal dimensions	Width of palate ‡	35.17	33.77	35.02	2.76	2.60	2.54	12.86	**0.000***
	Length of palate	33.52	32.78	33.63	3.05	2.89	2.71	3.09	**0.046***
	Height of palate ‡	12.23	11.82	13.18	2.42	2.67	2.41	3.26	**0.010***
	Palatal height index	30.89	31.56	33.02	4.70	5.87	5.16	2.02	**0.133**

*,** *statistically significant at 0.05; † ANOVA test; ‡ Kruskal-Wallis test*

Table 34 presents the descriptive statistics of the palatal height index forms and also summarizes the data for each class within the respective palatal height categories.

Table 34. Palatal height index forms calculated

Palatal height index	**N (%)**			**Mean**			**SD**		
Shallow palate	390 (97.5%)			30.94			4.84		
Average palate	1 (0.3%)			42			-		
High palate	9 (2.3%)			44.99			2.09		
Total	**400**			**31.29**			**5.25**		
	N			**Mean**			**SD**		
Palatal height index	**Class I**	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**
Shallow palate	210	161	19	31.12	30.37	33.74	4.77	4.72	5.82
Average palate	0	1	0	0	42	0	0	-	0
High palate	2	4	3	45.76	44.60	45.00	2.84	2.08	2.48
Total	212	166	22	31.26	30.79	35.28	4.96	5.21	6.72
	400			31.29			5.25		

Table 35 summarizes arch forms' descriptive statistics and distribution.

Table 35. The descriptive statistics of arch forms calculated by ratio.

Arch form	**N (%)**			**Mean**			**SD**		
Square arch	232 (58%)			44.44			15.28		
Oval arch	64 (16%)			41.46			17.23		
Tapered arch	104 (26%)			45.14			19.91		
Total	**400**			**44.49**			**17.30**		
Arch form of maxilla	**N (%)**			**Mean**			**SD**		
Square arch	260 (65%)			42.27			14.73		
Oval arch	65 (16.25%)			37.25			15.46		
Tapered arch	75 (18.75%)			37.79			15.91		
Total	**400**			**40.51**			**15.46**		
Arch form of mandible	**N (%)**			**Mean**			**SD**		
Square arch	204 (51%)			46.61			15.83		
Oval arch	64 (16%)			45.67			19.00		
Tapered arch	132 (33%)			52.50			23.91		
Total	**400**			**48.47**			**19.15**		
Arch form of maxilla	**N**			**Mean**			**SD**		
	Class I	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**
Square arch	132	111	17	33.35	29.30	28.96	7.68	8.26	8.19
Oval arch	41	23	1	49.44	50.08	49.07	2.27	2.18	-
Tapered arch	39	32	4	61.17	67.25	69.06	6.48	11.45	7.71
	212	166	22	41.58	39.49	37.16	13.05	17.48	17.73
Total	400			40.07			15.32		
Arch form of mandible	**N**			**Mean**			**SD**		
	Class I	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**	**Class I**	**Class II**	**Class III**
Square arch	106	91	7	34.37	32.38	40.16	7.79	7.71	4.76
Oval arch	37	26	1	49.35	49.41	51.13	2.20	1.92	-
Tapered arch	69	49	14	65.47	70.91	95.39	10.27	14.56	15.02
Total	212	166	400	47.11	46.42	75.80	16.05	19.56	29.22
	400			48.40			19.58		

5. DISCUSSION

The size and shape of teeth and dental arches have been the subject of numerous studies across the world. This has allowed for the comparison of different populations and the determination of patterns of variability between different teeth, and associations between and within dental arches (12, 54, 70, 74, 144, 216-218). In addition, the sample sizes used in these studies have also varied greatly, ranging from small to large. In particular, studies have shown that the size of the sample is an important factor in the accuracy of the results, and should be taken into consideration when attempting to draw conclusions from the data. Overall, tooth size and dental arch dimensions have been studied extensively in different populations, providing valuable insights into the wide range of variability in both. This has enabled researchers to gain a better understanding of how these parameters differ between populations, and how they are associated with one another.

This study evaluated the tooth size, tooth size discrepancy, and dental arch dimensions of Kosovar schoolchildren in different malocclusion groups and in relation to sex. The sample size and age distribution have been reported as representative of the population of Kosovo (209). Furthermore, in this study we selected the adolescent group (13–19 years) because their permanent dentition was complete, and the possibility of developing caries and the attrition of teeth in this age group was considered minimal.

Accurate and thorough documentation is essential in order to formulate a correct orthodontic diagnosis. This documentation should include the patient's medical history, as well as intra- and extraoral clinical examinations. Additionally, model analyses, radiological analyses, and cephalometric and photographic examinations should all be documented (219). It is crucial to document all the elements related to orthodontic diagnosis in a detailed and comprehensive manner. This further enables the doctor to make an informed and precise decision regarding the most suitable treatment plan for the patient.

Numerous studies in different population groups have evaluated tooth size and dental arch dimensions using dental casts. Dental measurements in this study were performed using a digital caliper and 3D orthodontic compass. Moreover, the accuracy of the measurements of tooth size and dental arch dimensions was tested.

Obtaining accurate measurements is not only important for diagnosis and treatment planning, but also for obtaining excellent stability. By measuring the size of the teeth, it is possible to ensure that the dental arch is properly balanced and that the patient will not experience any problems once treatment is complete. In conclusion, dental arch models are essential for orthodontic record keeping, diagnosis, treatment planning and evaluation, and case control studies.

New techniques and devices have been developed and are being extensively used in recent years to attain precise and reliable dental measurements (81). These innovative methods are expected to continue to play a crucial role in dental care. Nevertheless, due to the utilization of different measurement techniques, it has been challenging to draw comparisons.

It is important to acknowledge that despite our study's strengths, it has limitations as well. This study used a multistage cluster sampling approach, which may introduce bias due to clustering. The methodology chosen was based on practical constraints and considerations, as well as the population examined. This sampling method may be a valuable tool when it is difficult to obtain a simple random sample from a diverse and large population. However, it may not fully represent the population as a whole and could introduce similarities between clusters, potentially reducing sample variability. Thus, caution is necessary when making broad conclusions based on this study's results.

Furthermore, this study only focused on adolescents between 13 and 19 years old. Our sample consisted of a general population with different malocclusions. Therefore, our findings may not be generalized to other age groups or populations.

Another limitation was that the measurements were made using a 2D method rather than a 3D method. Future work should focus on Kosovar orthodontic subjects and use a 3D method for measurements, such as tooth sizes and dental arch dimensions, to allow for more accurate and comprehensive data interpretation.

Despite these limitations, multistage cluster sampling offered several strengths that bolster our study's credibility. First and foremost, it was selected for its practical feasibility in our research. Kosovo's large and diverse population presented logistical challenges, making a simple random sample unattainable. Multistage cluster sampling helped us navigate these challenges effectively, ensuring that our study could be conducted within the available resources and timeframe. Additionally, this method allowed us to collect data from various locations, allowing for a more holistic view of the country's population.

Moreover, we took specific steps to enhance the accuracy and reliability of our chosen clusters. The initial stage involved the random selection of cities, each serving as a distinct representation of different population characteristics within Kosovo. This deliberate city selection process contributed to cluster diversity, mitigating potential bias. The subsequent phase involved sending invitation letters to various schools within the chosen cities, further promoting representativeness. As such, the implemented methodology was tailored to ensure a broad representation of the Kosovo population.

By recognizing the limitations while emphasizing the practicality and strategic selection of clusters, our study benefits from the ability to draw valuable insights from a large and diverse population. The sampling approach, while not without limitations, has contributed to the study's strength and its ability to provide meaningful results.

5.1 Tooth size dimensions

Dental arch models are part of the orthodontic record and are essential for diagnosis, planning and evaluation of treatments and case control studies (220). Measurement of upper and lower MD tooth sizes is essential to establishing an accurate diagnosis, determining the right treatment plan, and obtaining excellent stability (26, 54).

According to some authors, knowledge of the average MD width helps in reshaping and recontouring of teeth, especially anterior teeth and smile design, in different malocclusions and sexes, to obtain satisfactory results (115, 221, 222).

In the present study, there were significant differences between males and females for all teeth in terms of MD width on both arches ($p<0.05$) (Table 15). In addition, males showed larger MD crown dimensions than females. The upper and lower canines in both jaws and sides were the most dimorphic teeth in Kosovar adolescents. In addition, the lower right canine had the greatest variation in MD tooth width (6.93%), while the lower right central incisor showed the least variation (2.26%) (Table 15). This larger dimension of MD width in males can be attributed to the Y chromosome, which is responsible for dentin thickness, and contributes to the width of a tooth. However, it does not contribute uniformly to all teeth (223).

Our results are consistent with previous studies conducted in different countries such as South America (11, 15, 22, 26, 61), Africa (16), the Philipines (19), Iceland (20), Pakistan (29), Nepal (32), India (37, 39, 232, 234), Malaysia (66, 224), Yemen (70), Iran (80), Colombia (215), Brazil (220), Greece (225), Bangladesh (227), Southern China (228, 229), Morocco (230), Turkey (38, 231), Saudi Arabia (233, 237), Sweden (33, 235), Jordan (236), and Iraq (238).

The shape of the first molars varies the least, while that of the upper laterals and lower incisors varies the most, as noted by Axelsson and Kirveskari. Compared to anterior teeth, posterior teeth show less variability in the deciduous and permanent teeth (20).

The most significant difference between sexes concerns the canines in both dentitions (11, 228) or only in the permanent dentition (25). Others have also suggested that the most significant difference is related to the canines, and the opposite in the maxillary lateral incisors (20). From another perspective, the upper and lower canines showed the largest sex differences in buccolingual and mesiodistal dimensions, followed by the mesiodistal width of the upper central incisor and the buccolingual of the upper first molar (19).

On the other hand, other studies have shown sexual dimorphism, with male dimensions being more significant than females in certain teeth, such as the upper central incisors (239); the lower canines (240); the first and second maxillary molars (40); the upper and lower second molars (37); the upper and lower molars (27); the lower canines and 2nd premolars (227); and both maxillary and mandibular canines (241, 242).

In contrast, reverse dimorphism has been reported in other studies for maxillary and mandibular canines (243); for mandibular second premolars (32); and mandibular incisors (228, 238). Acharya and Mainali explains this as a result of reduced dimorphism through human evolution (32). Consequently, both sexes have overlapping tooth dimensions due to this trend towards monomorphism (30). At the same time, Al-Rifaiy et al. found no significant differences in canine dimorphism between males and females (244).

According to a few authors, the canines were the most dimorphic in both dentitions, while the incisors were the least (116, 228, 245). In a sample of 543 South Jordanians aged 12 to 16, Alwaraweh et al. (246) measured the MD tooth size of the permanent dentition. They found that the maxillary lateral incisors and the mandibular central incisors had the largest differences in mesiodistal width. In contrast, the maxillary canines and first premolars showed the greatest stability in MD width.

Using dental models of the Nalgonda population with class I malocclusion, Rani et al. (241) found that the MD widths of the right and left maxillary and mandibular canines were significantly different between sexes, with values being greater in males than in females.
In a Pakistani population with class I malocclusion, Shahid et al. (29) measured the mesiodistal width as the distance perpendicular to the occlusal plane between the buccal and lingual surfaces. In particular, males showed higher values than females for mesiodistal crown diameter in upper lateral incisors, canines, first premolars, and lower lateral incisors.
In 2011, Fernandes et al. (220) compared tooth MD width (from 1st molar to 1st molar on both dental arches) in a sample of 100 dental casts from the Department of Orthodontics, Bauru School of Dentistry, in Caucasian, African, and Japanese subjects of Brazilian descent with normal occlusion and a mean age of 15.16 years. Among the three study groups, males had the highest MD widths. However, half of the variables showed statistically significant differences in females (upper lateral incisors and first molars; lower lateral incisors, canines, first premolars and first molars).
Using a sample of 100 Turkish dental casts, Ateş et al. (231) measured the MD width of all teeth except the third molars in both dental arches. Compared to other populations, Turkish dentition appeared to be less sexually dimorphic. The results indicated that eight maxillary variables and seven mandibular variables of MD dimensions were significantly larger in males. In both jaws, most variances were found in the anterior teeth.
In a longitudinal study, Yuen et al. (228) measured the diameters of MD crowns from the dental casts of 112 Chinese children aged between 5.68 and 12.31 years. The study found that male teeth were larger than female teeth for all teeth, except the mandibular central and lateral incisors. In both arches of the permanent teeth, the canines were the most dimorphic, while the incisors were the least dimorphic, which is in line with our study.
Australian Aboriginal teeth were larger in males and the differences were significant in five deciduous teeth (247) and all permanent teeth, except the lower first premolar (248).
Six of ten Icelandic deciduous teeth were significantly larger in males (249), and all but one of the permanent teeth were significantly larger in males (20). French Canadian males were found to have significantly larger teeth (250), and all teeth were larger in African American males (26). Nigerians had significantly larger teeth than their British counterparts (36).

In another related study, Bishara et al. (15) compared mesiodistal permanent dentition crown dimensions in three populations from Egypt, Mexico and the United States. They found statistically significant differences between the three populations.

Canines and molars were significantly larger in boys than in girls, while there were no significant differences between the incisors. The Mexican specimen showed the most significant sexual dimorphism, followed by the Egyptian and Iowa specimens.

In a study of 648 dental casts from 356 boys and 292 girls, Jat children, Kaul and Prakash (251) measured the mesiodistal dimensions of deciduous and permanent teeth. They found that the dimensions of males' teeth were generally larger than those of females. The differences were statistically significant for all teeth except the maxillary first premolars and the mandibular second incisors. Among the permanent teeth, the first molars showed the largest mesiodistal diameter, while the maxillary second premolars and mandibular first incisors were the smallest.

Lysell and Myrberg (235) examined data from 530 males and 580 females born in Sweden. They found that boys had larger MD width than girls in the primary and permanent teeth. The largest tooth width difference between boys and girls was found in the permanent canines (5-6%). The largest variation in MD tooth width was seen in the upper permanent lateral incisor (8.5%), while the upper first permanent molar had the least (4.6%). A large variation in the mesiodistal width of the upper permanent lateral incisors affects the relationship between the incisors and the buccal interdigitation.

In 1981, Potter et al. (19) measured the MD width in 252 dental casts of Tagalog Filipinos. The results show that males had larger teeth than females. The canines showed consistently high values in both arches and sides. In addition, the MD dimension of the maxillary central incisors showed the greatest sex variation.

In an odontometric study, 161 permanent teeth of Iraqis were cast in plaster and analyzed (78 males and 83 females) by Ghose and Baghdad (238). They measured the MD width of the teeth on both arches. In general, the results showed that the mean values in both arches were larger for males than for females. However, the difference was only significant in the canines and the lower right first molar. The most variable teeth were the upper lateral incisors and the first molars, while the lower central incisors were the least variable.

In 162 plaster casts, Richardson and Malhotra (26) found that the teeth of American Black males were larger than females in both arches for each tooth type, despite showing a similar tooth size pattern. The size of the mandibular second molar showed the greatest variability in males, while the central incisors showed the least variation of all the teeth in both sexes.

In 1957, Moorrees et al. (11) measured the maxillary and mandibular MD crown diameters of both dentitions on 184 plaster casts of North American children (91 males and 93 females, aged 3 to 18 years, longitudinally). They found that males had higher tooth crowns than females. As can be seen from the critical ratios, this sex difference was greater in the permanent teeth than in the deciduous teeth, and it was more evident for the canines than for any other teeth in both dentitions.

In their systematic review and meta-analysis, Da Silva et al. (252) observed that dental dimorphism occurs in different groups living in different geographic areas; However, it is impossible to establish a single value that applies to all populations. In addition, Smith et al. (253) confirm that the tooth size relationship depends on the individual sex and arch length. Moreover, several authors have claimed that factors such as: hereditary factors (254); bilateral differences (255, 256); environment (257); the effect of caries incidence (258); water fluoridation (259); and material changes (260, 261), can lead to conflicting results in different populations when comparing tooth sizes. Therefore, according to Fernandes et al. (220), evaluating tooth size in terms of clinical behavior, when choosing a tooth to extract and the possible amount of tooth stripping, can become indispensable as it can influence the treatment planning and prognosis.

Some authors (262, 263) have shown that studies of sexual dimorphism provide information about the evolution, behavior and dietary habits of a population or even an individual. In fact, sexual diversity depends on many factors, as reflected in the complex pattern found in most primates (228). Therefore, teeth may be larger in populations that eat more plant-based food than meat (231). The present study does not provide any information about which form of nutrition predominates in the Kosovar diet. However, we can assume that males consume meat more than females, although this is only a hypothesis.

In conclusion, Kosovars adolescents showed the greatest sexual tooth dimorphism in MD width dimensions, followed by BL width dimension, and MBDL and MLDB diagonal width dimensions (Tables 15, 16, 17, and 18).

According to Acharya and Mainali (32), BL width dimensions differ according to sex in different populations. In our study, males had larger buccolingual dimensions than females (Table 16). The upper right lateral incisor was the most dimorphic tooth (6.62%), followed by the upper and lower canines. In addition, the least variation showed the lower left first molar (2.68%) (Table 16).

Compared to other populations, Kosovars are similar to those in other studies conducted on Mexican, Egyptian and American populations (15), the South African Caucasoid population (16), a Filipino population (19), a Pakistani population (29), a Turkish population (31, 231), a Malaysian population (224), a North Indian population (251), an American populations (32, 264), and Australian Aboriginal population (265).

In a retrospective study, Babu et al. (266) estimated the BL measurements obtained from 132 pre-orthodontic casts (66 males and 66 females aged 15 to 25 years) in the South Kerala population. According to the results, males exhibited different percentages of sex dimorphism, and BL dimensions differed from those of females.

In the Anthropology Laboratory of the University of Granada, Viciano et al. (267) measured the buccolingual dimensions of the deciduous and permanent dentition in a sample of 269 Spanish individuals. A higher mean was found for 19 of 44 dimensions of permanent dentition in males compared to females in the maxilla, and in 27 of 44 dimensions in males compared to females in the mandible ($p<0.05$). However, the permanent lower central incisors showed no significant differences. On the other hand, the canine was the most sexually dimorphic permanent tooth in both jaws. This was followed by the mandibular second molar and mandibular and maxillary first molars.

In 2007, Acharya and Mainali (32) measured the BL dimensions and assessed sexual dimorphism in all teeth except the third molars in a sample of 123 dental casts in the Nepalese population. They observed that males had larger sizes than females. Canines were consistently the most dimorphic teeth and were significantly larger in males in terms of BL dimensions, which is in line with our study.

Using a sample of 100 Turkish dental casts, Ateş et al. (231) measured the BL width of all teeth except the third molars in both dental arches. According to the results, males had significantly larger BL dimensions than females.

An analysis of 30 study models by Otuyemi and Noar (36) compared BL crown dimensions in the permanent teeth of Nigerians and British with Class I, and found there were no statistically significant differences detected in the BL crown diameter.

A study by Bishara et al. (15) compared the buccolingual crown measurements in three populations: Egypt (54 subjects), Mexico (60 subjects), and the United States (57 subjects). Each subject had normal class I. These three populations differed statistically significantly. Mexican boys had significantly larger maxillary first and second premolars than boys from Iowa and Egypt. Iowa girls had the smallest buccolingual diameter compared to Egyptian and Mexican girls.

In a sample of 648 dental casts from 356 males and 292 females, Jat children, Kaul and Prakash (251) measured the buccolingual dimensions of deciduous and permanent teeth. Males had higher dimensions than females in both dentitions. Axelsson and Kirveskari (20) measured the buccolingual dimensions from 1010 dental casts taken from schoolchildren in northeast Iceland. They found that the dimorphism was greatest in the canines, exceeding 5% in the BL measurements of the upper canines. However, BL measurements of the upper lateral incisors showed a relatively minor difference of just over 1%, which does not line with our study. The males had larger dimensions than the females. Potter et al. (19) measured BL widths from 252 dental casts of the permanent dentition of Tagalog Filipinos. According to the results, males had larger tooth sizes than females. The BL dimensions of the upper first molars showed the largest sex differences. In contrast, our study showed that the lower right first molar showed the least variation.

On the basis of these results, it may be concluded that there is an apparent difference between populations in terms of the magnitude of sexual dimorphism (32).

Dentists, anthropologists, and anatomists need information about tooth size in human populations. In order to diagnose and treat malocclusions, orthodontists require accurate knowledge of tooth dimensions, since stable occlusion depends on correct intercuspation (268). Males' diagonal crown dimensions were larger than females' in the current study (Table 17, 18). The results of our study are consistent with previous results in other countries, such as Pakistan

(29), America (31, 223), India (37, 39), Turkey (38), Malaysia (224), Iran (234), and Spain (256).

In a Pakistani population study (2015), Shahid et al. (29) measured the diagonal dimensions (MBDL and MLDB) of 128 subjects with class I malocclusion using a digital caliper and a digital stereo microscope. They found that males showed higher values than females.

In 2013, Viciano et al. (267) measured the mesiobuccal-distolingual (MBDL) and mesiolingual-distobuccal (MLDB) crown diameters of deciduous and permanent teeth in a sample of 269 Spanish individuals. They found that the average tooth size was larger in males than in females.

Using a sample of 60 Turkish dental casts (30 males and 30 females) from a high school in Istanbul, Karaman (38) measured the MBDL and MLDB widths of all teeth except the third molars in both dental arches. The results showed that seven maxillary variables and ten mandibular variables of the MBDL and MLDB dimensions were significantly larger in males.

The difference was statistically significant ($p<0.05$). The lower teeth are the most dimorphic in the Turkish nation. The most important dimorphism was found in the lower canines, where the accuracy rate was the highest.

Pereira et al. (269) used a sample of 80 dental casts obtained from the School of Dentistry of the University of Lisbon. All participants had Portuguese ancestry (Portuguese parents by generation), 55 females and 25 males (the mean ages were 23 and 24 years). They measured the MDBL and MLDB of the upper anterior teeth (central incisors, lateral incisors and canines). They found that male values exceeded females in all dimensions observed. The canines showed the greatest difference ($p < 0.001$).

In our study, regarding the MBDL diagonal dimension, the most dimorphic tooth was the upper right lateral incisor (6.41%), followed by the upper and lower canines. In addition, the least variation showed the lower right second premolar (2.21%) (Table 17).

In contrast, regarding the MLDB diagonal dimension, the most dimorphic tooth was the lower right second molar (5.50%), followed by the upper and lower second molar and upper right canine. In addition, the least variation showed the upper right first premolar (2.17%) (Table 18).

According to other studies that show sex dimorphism, males have larger first and second maxillary molar dimensions than those of females (40); and also second molars in both the maxilla and mandible (37); and molars in both the maxilla and mandible (27).

Canine dimorphism has also been demonstrated in diagonal tooth dimensions (30, 35, 38). The molars also show a significant degree of sexual dimorphism (32). Using diagonal diameters (MBDL and MLDB), Mujib et al. (270) evaluated the degree of sexual dimorphism in the upper permanent canines and first molars in a sample of 100 upper dental casts (50 males and 50 females aged 17 to 25 years) in a population from Davangere. The results showed statistical significance, with males having higher diagonal measurements than females. The canines showed the highest accuracy, with MBDL measurements being more reliable, which also agrees with Karaman's study on a Turkish population (38). In addition, the MBDL of the molar crown was the most dimorphic measurement.

In a study with 200 subjects from the North Indian population, Manchanda et al. (37) found that the diagonal crown diameters of the upper and lower second molars exhibited more dimorphism than those of the first molars, with the exception of the MBDL dimension of a lower molar. These results were similar to the study by Zorba et al. (27). On the other hand, Manchanda et al. (37) found that the lateral incisors and premolars did not exhibit significant sexual dimorphism.

Recently, Sharma et al. (40) used diagonal odontometric measurements (MBDL and MLDB) of maxillary molars in a study sample comprising a total of 200 maxillary dental casts obtained from 200 participants (100 males and 100 females) aged 12 to 21 years from the North Indian population. Both the first and second maxillary molars were found to exhibit sexual dimorphism, with male dimensions being larger than females.

Zorba et al. (27) measured the diagonal diameters (MBDL and MLDB) of 344 permanent molars in 107 individuals (53 males and 54 females) from the Athens collection. Greek males were found to have larger molars than females. The most sexually dimorphic molars were the upper M2, lower M2, and lower M1.

The differing accuracy of sex classification of teeth between different populations can be explained by the fact that sex dimorphism is a population-specific phenomenon. The different patterns of sexual dimorphism between different populations result from genetic and environmental factors (27).

The size of human teeth has steadily decreased over the past 4000 years as a result of more advanced food preparation tools and techniques, as well as genetic mutations (271). Eating habits differ between populations and may influence the size of human dentition (231).

The present study also showed that males had higher crown height dimensions than females (Table 19). A study from Pakistan came to the same conclusion. In 2018, Shahid et al. (41) measured the crown height dimensions of 128 subjects (64 males and 64 females, mean age 19.4 ± 1.9 SD) with class I malocclusion. They found that males had larger crown height values than females in both arches. Sridhar et al. (272) obtained the same result in a study of the Chennai population in India. The sample consisted of 100 study models with class I malocclusion, in which the crown height of all the permanent teeth except the third molars was measured.

Measurements were done using a digital caliper, and the results showed that the crown height dimensions were higher in male teeth than in females. In both sexes, the upper and lower central incisors and canines had the highest values of crown height, while the second molar had the lowest value of crown height.

In another study, Melo et al. (273) evaluated the crown height of the six maxillary anterior teeth using digital calipers on plaster casts from 384 subjects with a mean age of 20.1 years obtained from the Faculty of Dentistry, University of Valencia (Spain). They found that the average height in males was 0.46 to 0.24 mm greater than in females, depending on the type of tooth. Other authors (44, 274, 275) have also reported sexual dimorphism, describing greater crown height in males than in females.

Rönnerman and Larsson (276) conducted a study exploring the clinical crown length of maxillary and mandibular central incisors in relation to different malocclusions (classes II1,II2,III, and IV). Their findings showed that the clinical crown length was greater in both the class II1 and class III groups compared to the class II2 and IV groups. It is worth noting that their study differed from ours as they included subjects with upper lateral incisor aplasia in group IV. Since our study did not encompass group IV, meaningful comparisons cannot be made. Similarly, Morrow et al. (277) also conducted a study and the results of their study were almost identical to the results of Rönnerman and Larsson's study. These findings support the use of the measurement results from Rönnerman and Larsson's study as reference values. Nevertheless, from an orthodontic perspective, their studies suggest that clinical crown height

can be a valuable diagnostic measure to determine deviations from “normal” due to the suspected effects of malocclusion or oral habits.
Volchansky and Cleaton-Jones (278) determined the clinical crown height of the permanent teeth of 237 Caucasian children between the ages of 6 and 16 years. They found that with increasing age, in all the teeth except the lower second molar there was a shift of the gingival margin towards the cement-enamel junction. In the lower central incisors, canines, second premolars and first molars, this trend leveled off after the age of 12. In the remaining teeth, the gingival margin continued to decline by age 16, the oldest group in the study, with a concomitant increase in clinical crown height.
Bassey (279) also measured the clinical crown heights of 2048 adult Nigerians and found that the clinical crown size gradually increased with age. He then compared the crown heights of the Nigerian population to that of Caucasians (278). In his article, he concluded that the Nigerian and Caucasian values were similar, but contradicted this in his summary, noting that Nigerians appear to have shorter clinical crowns than Caucasians. The Student's t-test for independent samples found no statistically significant differences between these published results and those of Volchansky et al. (280), suggesting no race effect.

In conclusion, our study of tooth size dimensions within a Kosovar adolescent population revealed significant sex dimorphism. This supports our objective and hypothesis. Based on these results, it is important to consider sex in orthodontic diagnosis and treatment planning in this population. Additionally, further research is needed to determine the genetic and environmental factors contributing to the development of sex differences in tooth size. We hope this study will help inform orthodontic decision-making and provide valuable research opportunities for future studies.

Numerous authors have studied the relationship between tooth dimensions and occlusion. The tooth dimensions of multiple occlusions have been determined and evaluated (18, 24).
Arya et al. (24) investigated mesiodistal tooth measurements in class I and II occlusion. For both sexes, no differences were found in relation to the occlusal categories, with the exception of the mandibular first permanent molar and the mandibular second deciduous molar, in which

class I demonstrated a larger measurement than class II. In contrast, our study investigated mesiodistal crown widths in three malocclusion classes and found significant differences between classes. Class I had the highest mesiodistal crown widths values for specific maxillary teeth (12, 13, 14, 22, 23, 24) and mandibular teeth (35, 36, 38), followed by Classes II and III (Table 23).

Approximately 300 white British males aged 16 to 18 were measured in equal groups for class I, II, and III dental occlusions and skeletal patterns by Lavelle (281). In class I, the mesiodistal and buccolingual dimensions were larger than in class II or III (0.6% and 0.7%, respectively). Moreover, maxillary teeth had larger mesiodistal and buccolingual dimensions, although these differences were greater than those in the lower teeth. The study findings highlight the importance of considering the dimensions of teeth when diagnosing dental occlusions and skeletal patterns. It was shown that patients with malocclusions show no differences in tooth size compared to patients without malocclusion (26, 282).

Unfortunately, due to the lack of literature, we were not able to compare our results with previous studies regarding other tooth size dimensions with different malocclusion classes.

5.2 Sex dimorphism for tooth size ratios and dimensions of the dental arches

Various authors have reported sex differences in tooth size ratios. The results of our study show that no significant difference was found between males and females according to Bolton's tooth size ratios (Table 20). The same results were obtained in previous studies reported by different authors (2-4, 8, 56, 57, 60-62, 64, 67-77, 88). They did not observe any sexual dimorphism in anterior and overall ratios.

On the other hand, some previous studies compared tooth size ratios between males and females and showed different results (11, 18, 24, 26, 50, 78). For example, Moorrees et al. (11) only showed sex differences in the overall ratio. Lavelle (18) compared the overall and anterior tooth ratios between males and females and found that males had larger ratios than females. Smith et al. (50) found that the overall and posterior ratios were significantly greater in males than in females. Richardson and Malhotra (26) reported no differences in anterior or posterior inter-arch tooth-size proportions. Mollabashi et al. (79) on the Indian population found a significant sex difference in the posterior and overall ratios. Oktay and Ulukaya (81) in a Turkish population, only noted sexual dimorphism for the posterior ratio. Strujić et al. (93) in a Croatian population only found sex differences in the anterior ratio.

On the basis of these finding, therefore, variations in the literature regarding tooth size ratios and sex show that they must be calculated separately for each population. In summary, most studies show that sex does not make a significant difference in tooth size ratios.

According to Morrison (283), the irregularity index serves as an epidemiological tool because it: a) improves the accuracy of screening examinations conducted in nonclinical settings; b) is easy to perform; c) requires little technical skill, and d) produces rapid results.

According to our findings, the mean value of crowding was higher for maxillary incisors than in mandibular incisors (Table 13). This finding is supported by some studies (118, 133) that confirm that the increase in the crowding of upper incisors is more distinct than the increase in lower incisors during this period of human development. Sampson (284) stated that breathing through the mouth, decay, and teeth removal are the causes of crowding of incisors. However, our study excluded the subjects with extractions, extensive caries, and large fillings, due to the possible effects on occlusion.

Moreover, Tibana et al. (111) stated that oral breathing, as a parafunction, is known to have severe effects on stomatognathic structures. An assessment of breathing could verify the association. It would be interesting to consider this in future studies, although our methodology did not take it into account.

Our study also found differences in terms of the incisal irregularity index in males and females, with males having higher incisal irregularity than females in both jaws (Table 21). In contrast, Carter and McNamara (118) found that only mandibular incisor irregularity differed between sexes. Males exhibited more incisor irregularity than females; however, the change in irregularity was the same in both sexes. A few studies have reported that mandibular incisor irregularity increases on average over the course of a lifetime, regardless of orthodontic therapy. As a result, tooth retention, interproximal reductions, or limited orthodontic treatment are needed when incisor alignment is required long-term (285).

In contrast, Buschang et al. (110) showed that adult females with class II malocclusions had more maxillary incisor irregularities and less mandibular incisor irregularities than those with class I malocclusion. Meanwhile, Ghaib et al. (286) found that male subjects with a class II malocclusion had more upper incisor irregularity, while female subjects with a class I malocclusion showed a higher prevalence of crowded mandibular incisors.

Overjet values in our study differed between males and females, indicating that males had average values higher than females (Table 21). This is in agreement with the findings of Lara-Carillo et al. (287) in the Mexican population, which reported that males had greater overjet than females in both Mazahua and Mestizo adolescents. In the most recent study, Olliver et al. (288) concluded in a review cohort study that overjet was about 0.5 mm higher, and overbite was about 0.5 mm smaller in middle age than in adolescence. As well as sex differences, females had higher overjet and overbite at age 45 than males. In contrast, several previous studies found no significant differences between men and women. In their study, Staley et al. (289) found that the sexes had similar dimensions and did not differ significantly.
In 1998, Carter and McNamara (118) reported in their longitudinal study, which consisted of 53 subjects' dental casts, that untreated males had an overjet decrease of 0.6 mm between 13.8 and 17.2 years of age, whereas no difference was found in females. Furthermore, the overjet in the University Michigan Growth Study sample aged 17 to 48 did not change by sex. When Bishara et al. (290) studied individuals aged 5 to 15, they reported minimal changes in overjet. In a later study with a group aged 25 to 45, Bishara et al. (133) corroborated the same findings. Further, Akgül and Toygar (291) analyzed 14 females and 16 males over a 22 to 32-year period. They reported that the overjet did not show significant changes in either males or females. More recently, Stern et al. (292) found no statistical differences in overjet between men and women from birth until 26 years of age, in their longitudinal study on untreated German children with normal occlusion.

The present study found no significant differences between males and females with respect to overbite (p-value > 0.05) (Table 21). Several previous studies found similar results, such as Carter and McNamara (118), who found no difference in overbite between males and females, and Bauerle (293), who found no significant sex differences at any age. Fleming (294) also found no differences in the extent of overbite in males and females for Class I malocclusions, although the mean values for females tended to be slightly higher. More recently, Stern et al. (292) found no statistical differences in overbite between males and females from birth to age 26 in their longitudinal study of untreated German children with normal occlusion.

In contrast, in the population of Mexico, Lara-Carillo et al. (287) reported that males had a greater overbite than females. On the other hand, Akgül and Toygar (291) studied 30 participants from 22 to 32 years. In females, the overbite increased significantly.

However, according to Bergersen (117), there is a consensus that overbite usually increases during mixed dentition and decreases during the teenage years. Researchers also agree that the rise in overbite may be caused by the increase in cuspid arch width, which typically occurs when the permanent maxillary incisors and canines erupt (114, 139, 295). Furthermore, the overbite depth differences between men and women are insignificant (293, 294, 296).

In conclusion, Harris and Smith (297) revealed that, whereas genetic variation affects arch width and arch length to a substantial degree, more than genetic variability among families, environmental factors influence occlusal variables, including overjet, overbite, molar relationship, crowding, and rotations.

Our results showed significant sex differences in arch width. Males had larger arch width dimensions than females (Table 22). Several studies came to similar results as ours. Recently, research by Yadav et al. (298) on a sample Nepalese population showed that the widths between the canines and the molars in both the maxilla and mandible were wider in males than in females. Hashim and Al-Gandhi (233) also found in a sample Saudi Arabian population that the inter-canine width and inter-molar widths were larger in both dental arches in males than in females. In the study on the Colombian population (2009), Alvaran et al. (299) also showed that males had significantly wider arches than females did.

In the last century, Yones (176) found a highly significant difference between sexes in Saudi and Egyptian samples. The mean values of the inter-canine and inter-molar widths of the Egyptian and Saudi samples were significantly larger in males than in females.

In 2009, in a study of a Mexican population, Lara-Carillo et al. (287) reported that the arch widths of Mazahuan and mestizo teenagers differed between sexes; Males had larger diameters in both ethnic age groups. In a sample of Saudi adults (2018), Alkadhi et al. (121) reported that

Saudi males had smaller inter-canine widths than Caucasians and Southern Chinese. However, the widths in females were larger compared to Caucasians and smaller compared to Southern Chinese. In addition, Saudi males and females displayed larger inter-molar widths compared to Caucasians, but smaller inter-molar widths compared to South Chinese.

Further, in a comparative study of arch widths, Staley et al. (289) found that males with normal occlusion had significantly greater dimensions than females in five of the six arch width variables, while in class II, division 1, the males had larger dimensions when compared to the females. However, the difference was not significant only in the maxillary and mandibular inter-alveolar widths. In a population study in South China (2009), Ling and Wong (128) reported that all male maxillary and mandibular arch widths were significantly larger than female arch widths. In a longitudinal study, Bishara et al. (136) found that the inter-molar width in the maxilla and mandible was greater in males than in females.

In his longitudinal study, DeKock (135) reported that in female subjects the mean arch width in each arch showed no significant change over the 14 years from 12 to 26. In males, there was a small, but statistically significant increase in arch width from 12 to 15 years of age.

The results of our study also show significant differences between males and females in terms of arch length (Table 22). In addition, males showed higher dimensions than females. In 2018, Alkadhi et al. (121) showed that Saudi males and females had longer arch lengths compared to Yemenis, although they measured the arch length at different points than in our study. In 2015, Shahid et al. (29) reported that Pakistani males had larger arch length dimensions than Pakistani females, even though their sample consisted of class I subjects.

Hashim and Al-Gandhi (233) found in a sample Arab population that the arch length in both dental arches was greater in males than in females. Lara-Carillo et al. (287) in a population in Mexico reported that males had longer arches than females in both Mazahua and Mestizo adolescents. In contrast, Alam et al. (144) found no significant differences in the length of both arches between males and females in a sample of 53 Malaysian subjects.

In addition, our study also found that males had larger dimensions than females in terms of arch perimeter dimensions (Table 22). Lara-Carillo et al. (287) observed in the population in Mexico that males had larger arch perimeters than females in both Mazahua and Mestizo teenagers. Shahid et al. (29) showed that males had a larger arch perimeter than females in a sample Pakistani young adult population with class I malocclusion. These two studies were consistent with ours, although their sample included only class I subjects.

Conversely, Alam et al. (144) found no significant differences in arch perimeter of both arches between males and females in a sample of 53 Malays with class I malocclusion.

In a longitudinal study of occlusal changes in 27 young adult Caucasian Brazilians with normal occlusion, Tibana et al. (111) also showed no significant sexual dimorphism regarding arch perimeter of both arches.

In 2020, Stern et al. (292) found, in a longitudinal study of 31 untreated German subjects with normal occlusion, that upper and lower posterior and total arch perimeters were significantly larger in male subjects due to late mixed dentition. Subsequently, males tended to have larger dimensions for these parameters.

Regarding the arch form, no significant difference was found between sexes in the arch form of the mandible in the present study (Table 22). On the other hand, there was a significant difference in the arch form of the maxilla, with females having larger dimensions than males. In this study, we used an arch form formula to describe the arch form of both arches by measuring the landmarks on the study cast models. This was in line with a study of 600 Turkish subjects (362 girls and 238 boys), aged between 14 and 19, among whom 200 were Angle Class I, 200 Class II and 200 Class III, where Olmez and Dogan (300) in pretreatment mandibular dental casts observed that there were no significant differences between sex and mandibular arch form variances.

Our study found that most Kosovar adolescents had square arches (58%), followed by tapered arches (26%) and oval arches (16%) (Table 35). In contrast, in a study of Indian and Malaysian populations (2018), Zaaba and Jain (301) found that subjects in both populations had tapered arch forms. In the Indian population, most of them had tapered arch forms and the rest had ovoid arch forms with no maxillary square arches. On the other hand, in the Malaysian population, although most had tapered arch forms, there were also some with ovoid maxillary arches and some with square arch forms.

Further, Othman et al. (302) reported in their study that most Malaysians had ovoid maxillary arches, followed by tapered and square arch forms. However, the authors of these studies did not find any sex differences.

Although some studies reported that males have a wider arch form than females, there is general agreement that there are no sex differences in arch form (303, 304).

In terms of arch depth, our results showed significant differences between males and females. In terms of the arch depth of the upper jaw, males had smaller dimensions than females. In contrast, females had smaller dimensions than males of the arch depth of the lower jaw (Table 22).

In the last century, DeKock (135) reported in his longitudinal study that the mean values for both maxillary and mandibular arch depth for each sex throughout decreased the period studied with increasing age, with a smaller ratio of change after age 15 years. The mean decrease in mandibular arch depth from 12 to 26 years of age in male subjects was 3.2 mm, which is a decrease of 10%. In female subjects, the mean decrease in mandibular arch depth was 2.6 mm, representing a decrease of 9%.

In 2018, in a study of Saudi adults, Alkadhi et al. (121) showed that Saudi males and females had greater arch depth than Yemenis, although they measured arch length at different points than in our study.

Contrary to our study, in a cross-sectional study of 110 Pakistani subjects in different malocclusion groups (2010), Ahmed et al. (305) showed no significant differences between males and females in the arch depth of both arches between the three groups of malocclusion.

The results obtained from our study showed that within the palatal dimensions, there were significant differences between sexes, with males having larger dimensions than females (Table 22). This was in line with a cross-sectional study of 300 dental casts from Jordanian adults and children. Mustafa et al. (201) reported that palatal dimensions, reflecting palate size, were significantly larger in males than females. However, they used different measuring points than ours. In their opinion, this strongly suggests that the palatal dimensions and overall size are sexually dimorphic.

In a study of 32 pairs of Caucasian twins, Riquelme and Green (185) showed that the mean intra-pair variances of monozygotic and dizygotic twins values do not differ significantly between the different sexes. The palatal width, height, and length dimensions revealed a significant component of hereditary variability. Therefore, the authors proposed heredity as a strong etiological factor of malocclusions involving palatal dimensions. It has also been suggested that appropriate orthodontic or orthopedic procedures should be utilized at an early age to diminish or prevent undesirable genetic influences on the width, height and length of the palate. However, the researchers concluded that these palatal dimensions are not recommended for diagnosing zygosity in twins.

In the present study, the width of the palate was significantly larger in males than in females (Table 22). This was in line with the study by Amirabadi et al. (191) of a sample of 237 Iranian children, showing that males had greater palate dimensions than females. Furthermore, it was also consistent with the research of Redman et al. (192), who found that the average width of the male palate is greater than that of the female.

In 2012, the results of a study of the Class I Iraqi Arab adult population (200) indicated that the males had a larger palate width with a very highly significant sex difference. In class II, males had a larger palate width than females, with a non-significant difference. In comparison, conversely, class III showed a slightly larger palatal width in females with a non-significant difference. Also in the research by Borgan et al. (306) in a sample Jordanian population, the width of the palate was significantly higher in males than in females.

According to the literature, the inter-molar palatal width was larger in males than in females, including studies by Al-Zubair et al. (199), Staley et al. (289), and Raberin et al. (307).

However, it may be noted that the width of the palate appears to vary in different parts of the world, as do many anthropometric measurements that vary from one ethnic group to another (189).

The results of the current study report that the length of the palate was greater in males than in females (Table 22). This was in accordance with the study by Redman et al. (192) on a sample

of 1098 children from Minnesota, aged 6 to 18 years, and 224 adult Minnesotans, where they observed that the average palatal length of the males was greater than of the females.
Conversely, in the study of the Yemeni population (199), the palate length was significantly higher in females than in males. Furthermore, in the research by Nahidh et al. (200) regarding the Iraqi population, the results indicated that males in classes I and II had greater palatine lengths with a non-significant sex difference. In contrast, class III females showed greater palatal length, buth with a non-significant sex difference. According to the authors, this is due to the increase in overjet in males in class II, and vice versa in class III.

On the other hand, the palate height values in the current study showed a significant difference between sexes, with males having larger dimensions than females (Table 22). In contrast, in the study of the Iranian population with normal occlusion (191), there was no significant difference in palatal height in the molar area between males and females. The same result was also found in the research into an Iraqi population (204), no sex differences were reported.
On the other hand, in the study of the Iraqi Arab population (200), palate height was greater in males than in females in classes I and II, and vice versa in class III, with a non-significant sex difference.
The Thilander study (186) showed that the palate height at the molar site was greater in females than in males. In contrast, in Al-Zubair's study (199) males with class I occlusion had greater mean palatal height values than females. However, he used the mesio-lingual cusp tip instead of the central fossa of the permanent molar. According to Amirabadi et al. (191), these differences can be attributed to ethnic differences in the groups studied.
In summary, according to Yones (176), the sex difference is due to the fact that bony ridges, crests, and alveolar processes are smoother and smaller in females than in males. The average weakness of the female muscles also plays an important role in measuring face breadth, profile angle, and the width and height of the maxillary arch.

Regarding the palate height index, our results showed no significant differences between males and females (Table 22). In addition, the research by Amirabadi et al. (191) of an Iranian population with normal occlusion, showed no statistically significant difference between the sexes. Conversely, Redman et al. (192) observed in their sample of 1098 Minnesotan children aged 6 to 18 years and 224 adult Minnesotans, that the average palate height was greater in males than in females. These controversial results are due to differences in study population and methodology (191).

In conclusion, the present study aimed to investigate dental arch dimensions, tooth size ratios, and palatal height index values, with a particular focus on assessing whether sexual dimorphism plays a significant role in these dental parameters. Our findings revealed that while significant sex differences exist in various dental arch dimensions, including arch width, arch length, arch perimeter, arch form, and palatal dimensions, no significant differences were observed between males and females in terms of Bolton's tooth size ratios.

As a conclusion, while our study confirmed significant sex-related differences in some dental arch dimensions and the palatal height index, it refutes the hypothesis of sexual dimorphism in tooth size ratios, in agreement with the majority of the existing literature.

5.3 Tooth size discrepancy

Tooth size discrepancies have been investigated all over the world in order to compare populations with specific features and identify trends of variability among dental arches. Their significance in orthodontic diagnosis is well documented in scientifically published works. The orthodontic community has acknowledged the importance of the interrelationship between the maxillary and mandibular teeth to complete treatment (62).

In Bolton’s study, only 55 respondents took part, of wich 11 were non-orthodontically patients, and 44 were orthodontically treated with ideal class I occlusion.

The investigations of Bolton in 1958 and 1962 (12, 54) resulted in the creation of two formulas for measuring tooth size discrepancies, which were easier to apply clinically for dental cast measurements.

It has proven to be a simple analysis and has been used in many studies worldwide in different populations. Following the same pattern, this study used these formulas for Kosovar adolescents.

According to our research, the average anterior tooth size ratio was 79.81 percent, with a standard deviation of 2.95, which was higher than in Bolton's study (77.2, with a standard deviation of 1.65) (Table 12). Similar results to ours have been obtained from numerous studies on populations of Americans (50), Chinese (57), Arabs (63), Jordanian (67), Iranians (79), Syrians (87), Turkish (89), Polish (92), Lithuanian (94), and Indians (96) (Table 1). According to the authors, these higher values can be explained by the fact that Bolton's sample consisted of only class I occlusions. Other reasons might be the differences between samples and populations. In a study on a sample of the Iranian population, Fattahi et al. (80) showed an anterior ratio of 79.01 with a standard deviation of 2.8. In another study, Uysal and Sari (78) in a Turkish population showed an anterior ratio value of 78.26 with a standard deviation of 2.82. However, this study, which used Bolton's analysis, was in disagreement with previous studies by Hashim et al.(4), Bolton (12, 54), Cançado et al. (49), Ta et al. (56), Crosby and Alexander (60), Ricci et al. (72), Ismail and Abuaffan (73), Freeman et al. (84), and Al-Tamimi and Hashim (86), who found that anterior ratios averaged between 77.2 and 77.8. On the other hand, several studies, namely Machado et al. (2), Endo et al. (8), Paredes et al. (65), Kachoei et al. (69), Al-Gunaid et al. (70), Hyder et al. (71), Bugaighis et al. (74), Mujagić et al. (75), Mishra et al. (77), Uysal and Sari (78), Mollabashi et al. (79), Bernabé et al. (88), Akyalçin et al. (89), Al-Khateeb and Alhaija (90), Mirzakouchaki et al. (91), Zerouaoui et al. (97), and Mohammad et al. (98) found that the anterior ratio for the average population ranged from 78.0 to 78.54, which is an insignificant difference (Table 1).

Moreover, in the present study, both sexes and all malocclusion groups showed an average overall tooth size ratio of 92.89 percent with a standard deviation of 2.62 (Table 12). This was also higher than the value of 91.3± 1.91 in the Bolton study. The results of other studies from several countries, such as Portugal (2), America (50), Sweden (52), Saudi Arabia (63), Jordan (67), Yemen (70), South Telangana (76), Iran (80), Syria (87), Lithuania (94) and Morocco (97), showed similar results to ours.

On the other hand, our study was in disagreement with some previous studies by Abdalla Hashim et al. (2), Hashim et al. (3), Cançado et al. (49), Crosby and Alexander (60), Santoro et al. (61), Paredes et al. (65), Hyder et al. (71), Ricci et al. (72), Ismail and Abuaffan (73), Bugaighis et al. (74), Mujagić et al. (75), Mishra et al. (77), Uysal and Sari (78), Fattahi et al.

(80), Freeman et al. (84), Al-Tamimi and Hashim (86), Bernabé et al. (88), Akyalçin et al. (89), Al-Khaateb and Alhaija (90), Wędryechowska-Szulc et al. (92), Strujić et al. (93), Khan et al. (95), and Mohammad et al. (98). They all showed lower values than ours. The differences in the populations and samples of the two studies could explain these findings. Bolton used a small homogeneous group (55 Caucasian females) with excellent occlusion, whereas our study was conducted on schoolchildren and included 400 non-orthodontic subjects of both sexes and different malocclusions.

The current study shows an average posterior ratio of 105.99 with a standard deviation of 3.74 (Table 12). This ratio was not part of Bolton's research, but Smith et al. (50) were the first to describe the relationship of the ratio between the premolars and the first molar. Their results showed a value of 104.82. Compared to our study, other studies did not show much difference. A study by Nie and Lin (57) of a Chinese population reported a posterior ratio of 105.26 ±4.29 in male subjects and 104.77±4.03 for female subjects with different classes of malocclusion. The study by Oktay and Ulukaya (81) of a Turkish population showed an average posterior ratio of 105.70 for male subjects, and 104.91 for female subjects. A value of 104.12 was found by Fattahi et al. (80) with a standard deviation of 3.40. In conclusion, this analysis shows that the mean and standard deviation of the posterior ratio are generally higher than other variables. This is probably due to the fact that premolars, particularly first molars, have high mean values when measuring mesiodistal width.

While discrepancy is more easily represented by a value than by the amount of discrepancy, it is not a common research variable. Despite the proportional dependence on the Bolton coefficient for the anterior tooth ratio, discrepancies in both jaws are calculated in everyday practice. In general, what matters is the discrepancy value in the jaw where it is positive. As a result, it determines how much interproximal enamel reduction is required (308).
The current study reported an average anterior discrepancy of -1.59 with a standard deviation of 1.79 (Table 12). A negative discrepancy reveals how much mesiodistal diameter is needed to achieve an ideal occlusion in the anterior part of the upper arch, and the diameter must be replaced. As opposed to this, Stujić et al. demonstrated in another study among the Croatian population, that the mean anterior discrepancy value was -0.49±1.55 mm (308).

On the other hand, the total discrepancy indicates how extensive the stripping must be throughout the dental arch, based on the value of the discrepancy in millimeters. The total discrepancy (in mm) is the same as the anterior discrepancy (in mm), and they are calculated for both the upper and lower jaws (308).

This study also shows an average overall discrepancy of -1.69 with a standard deviation of 2.73 (Table 12). A negative discrepancy, in general, indicates how much mesiodistal diameter is missing in the total upper arch. Contrary to this, in a sample Croatian population, Stujić et al. found figures of -0.33±2.10 mm (308).

The fact that tooth size variations are not systemic proves that populations differ in terms of tooth size ratios between arches. The variations in maxillary tooth size by population and sex are not correlated with differences in mandibular tooth size, so that different tooth size ratios will be observed between arches (50).

The current investigation demonstrated that only the anterior ratio differed significantly among the malocclusion classes ($p<0.05$), but neither the overall ratio nor the posterior ratio differed significantly (Table 28). On the other hand, Oktay and Ulukaya (81) and Strujić et al. (93) reported contrasting findings. There were no significant differences in the anterior tooth ratios among the malocclusion classes. They did, however, discover substantial changes in the overall and posterior ratios.

Moreover, several previous studies in different populations reported no significant variations between the malocclusion classes in anterior and overall ratios (61, 68, 78, 90, 94, 309). According to Crosby and Alexander (60), respondents from all different classes had values similar to Bolton's. In addition, no statistically significant differences were found between the classes in different groups. Also, neither the anterior ratio nor the posterior ratio showed any statistically significant differences between skeletal classes in the study by TaTa, Ling, and Hägg (56).

Other researchers (57, 309) reported that overall tooth size ratios were higher in class III than in classes I and II. According to Araujo and Souki (62), class III subjects had a substantially larger anterior tooth size discrepancy than class I and II subjects. Their study shows a statistically significant difference between respondents in class III and those in other groups. However, there is no difference between respondents in classes I and II.

This tendency towards greater tooth size proportions in class III was observed in the Chinese population by Ta et al. (56). Alkofide and Hashim (63) also observed it in a Saudi population divided into groups according to class. Discrepancies were not statistically significant according to class, except for the anterior ratio in class III, which differed from other groups. Johe et al. (99) recommend that tooth size discrepancies should be evaluated and addressed while other treatment issues are considered. A diagnostic orthodontic treatment plan is only part of the process. Developing a logical and comprehensive treatment plan requires consideration of other factors, such as: soft tissue, skeletal and other dental evaluations. Bolton (54) suggested in 1962 that a deviation from the average of over 1 SD indicates the requirement for diagnostic attention. His study found that 29% of his private practice patients had tooth-size disparities of over one standard deviation. The study of Belo Horizonte inhabitants by Araujo and Souki (62) indicated a high prevalence and, consequently, emphasized the importance of analyzing discrepancies in the anterior segment. According to the study, 56% of respondents had anterior ratios over one standard deviation, compared with Bolton (12) and Richardson and Malhotra (26) of 29% and 33.7%, respectively. The wide distribution of respondents explains the large genetic heterogeneity of the Brazilian population. In the same survey, 20.7% of respondents had ratios over two standard deviations. According to the authors, subjects with classes I and III had a higher prevalence of discrepancies than subjects with class II.

In contrast, other researchers (60, 84) interpreted it differently, as more than 2SD from the Bolton standard. Freeman et al. (84) observed that 30.6% of 157 subjects had anterior ratios over two standard deviations from the Bolton distribution. In the overall ratio, it was much smaller, about 13.4%. Most subjects were beyond two standard deviations, according to the study. The high error was probably caused by the method of collecting the data (measurement). Twenty-four examiners participated in this study, which amounts to 6.54 respondents per examiner. The calibration of testers is affected by this, leading to measurement and, ultimately, result errors.

Crosby and Alexander (60) showed that the total amount of anterior TSD for all respondents was slightly smaller at 22.9%. The research showed, in terms of anterior and overall discrepancies in mm, that the lower jaw had a larger discrepancy (a tendency of the ratio towards higher values) than the upper jaw. Anterior discrepancies that exceed two standard deviations are found in 9.2% of subjects. A discrepancy in the lower arches was observed in 13.8% of subjects. According to the authors, this would likely lead to recurrence after orthodontic therapy, especially if the width of the lower front teeth is not corrected (stripping). A study by Bernabé, Major, and Flores-Mir (88) of Peruvian adolescents showed 16.5% of subjects exceeded the upper limit and 4% were below the lower limit of two standard deviations from Bolton's original distribution. In the overall ratio, there was an even distribution of 2.5%, so 5% in total. Another study, conducted in the Dominican Republic (61), showed that 11% of respondents had a significant deviation from the overall ratio, and 28% had a significant deviation from the anterior ratio, i.e., exceeding the limit of two standard deviations.

Some studies have defined the prevalence of tooth size disparities and reported different results. In the current study, the frequency of a significant disparity (more than 2 SD) in the anterior ratio was 41.37 percent (Table 30), which is in accordance with earlier findings in other populations (60, 68, 71, 84, 92). Higher values indicate a trend for the mandibular tooth to be oversized in participants with class III. This suggests that the anterior maxillary teeth were smaller in subjects with class III than in class II and class I. According to Akyalçin et al. (89), there may have been considerable individual population diversity in the growth pattern among the respondents. In contrast, percentage values for anterior discrepancy ratio have been reported in Japanese (8), Southern Chinese (56), Dominican American (61), Brazilian (62), Jordanian (67), Yemeni Arabian (70), Libyan (74), Nepalese (77), Turkish (78,81), Croatian (93), and American (99) populations, and they showed lower values (8, 56, 61, 62, 67, 70, 74, 77, 78, 81, 93, 99) than ours. This could be due to population-specific features.

The incidence of a significant overall ratio discrepancy in the current study was 23.79 percent (Table 31), which was similar to the results from studies carried out in Iranian (79) and Turkish (81) populations. In contrast, Bolton (12, 54) and Proffit (7) observed under 5 % of individuals with an overall ratio disparity of more than 2 SD. However, their investigations comprised individuals with perfect occlusion, which could be assumed to be more typical of the normal community than of orthodontic patients. The prevalence obtained in the current study, however, was higher than reported in previous studies (7, 8, 12, 54, 61, 67, 71, 74, 77, 81, 88, 92, 93). Of these studies, including ours, Akyalçin et al. (89) had the greatest value. Their sample was drawn from an orthodontic population, which could explain why they had the highest percentage of anterior tooth size discrepancies.

The higher frequency of statistically significant anterior tooth size discrepancies in the Kosovar population compared to overall discrepancies suggests a significantly larger number of participants with proximal anterior tooth size disparities more than 2 SD from the Bolton mean versus participants with overall disparities. The reason might be that the front teeth, particularly the upper and lower, are significantly more prone to tooth size deviations. In other words, the anterior region exhibits the most significant variability in mesiodistal tooth sizes (78, 79).

These results suggest that national criteria for clinical status are required. As Bolton statistics are not representative of the non-orthodontic Kosovar population, these data should not be used in regular orthodontic diagnosis and treatment of Kosovar orthodontic patients.

Moreover, it emphasizes that the prevalence of the Bolton discrepancy may differ between populations with different occlusal disorders, which supports our hypothesis. Therefore, clinicians need to be aware of the frequent occurrence of TSDs when assessing and treating orthodontic patients.

As a result, despite the malocclusion group, sex, or population, conducting Bolton's analysis routinely is strongly encouraged (93, 99, 102).

5.4 Dimensions of dental arches

According to Barrow and White (139), when planning treatment procedures, orthodontists should expect a moderate increase in arch width, particularly in the anterior regions, until the permanent canines erupt. After this time, they should expect some decrease in arch width in both the anterior and posterior regions.

The results obtained in our study found significant differences between classes in the arch width of the maxilla, where class I showed significantly larger inter-canine, inter-premolar, and inter-molar arch widths, followed by classes III and II. In contrast, the arch width of the mandible did not differ significantly among different malocclusion groups (Table 33).

Different authors have investigated inter-canine widths, and their results differ. In the present study, the class I group showed a significantly greater maxillary inter-canine width compared to the classes II and III groups (Table 33). The results are consistent with the studies by Staley et al. (289), Huth et al. (310), and Kumari et al. (311) but different from the study by Sayin and Turkkahraman (312).

With regards to inter-molar width, as in the present study, Staley et al. (289) and Huth et al. (310) also reported similar findings of larger inter-molar width in class I malocclusion compared to classes II and III. On the other hand, Basaran et al. (313) discovered that maxillary inter-molar widths were significantly greater in class II, class I, and class II division 1 groups, respectively. Lux et al. (137) found significant differences among groups of malocclusions (normal occlusion, class I, class II div.1 and class II div.2). They showed that maxillary inter-molar widths were smaller in the class II/1 group than in the class I and the good-occlusion groups, in both boys and girls.

During the last century, in a longitudinal study, Bishara et al. (129) found that the inter-molar width in the maxilla and mandible was larger in normal subjects than in subjects with class II division 1 malocclusions. Hashim and Al-Gandhi (233), on a sample Saudi Arab population, found no significant difference in the arch widths between the malocclusion and normal occlusion groups.

Alvaran et al. (299) showed in a sample Colombian population that class II subjects had significantly narrower anterior maxillary widths than those with normal occlusion or class II malocclusion. Class I subjects had narrower inter-premolar widths than those with normal occlusion or class II malocclusion. In another study, Ling and Wong (128) discovered that while Chinese dental arches appeared to be very wide compared to those in white people, inter-canine and inter-premolar width variations ranged from 2 to 3 mm. Furthermore, Lara-Carillo et al. (287) from Mexico reported that the Mazahua population had larger inter-canine and inter-molar widths, while in the Mestizo population they were smaller.

On the other hand, in the study of a Turkish population, Uysal et al. (314) found that the maxillary interpremolar width, maxillary canine, premolar, and molar alveolar widths, and the mandibular premolar widths were significantly narrower in subjects with class II division 1 malocclusion than in the normal occlusion sample.

Also, in another study conducted by the same authors (315) in a Turkish population with normal occlusion and III malocclusion, it was found that maxillary inter-premolar and inter-molar width measurements were significantly narrower in the class III group than in the normal occlusion sample. In the class III group, the alveolar mandibular inter-canine and inter-molar widths were significantly larger. On the other hand, the measurements of lower canine and premolar alveolar width were statistically significantly larger in the normal occlusion group than in the class III malocclusion group. Huth et al. (310) showed that maxillary arch widths were smaller in class II than in normal occlusion. The mandibular arch widths were also narrower in class II than in normal occlusion.

Furthermore, Staley et al. (289) conducted a comparison of dental and skeletal arch dimensions in patients with normal occlusions and class II division 1, dentally and skeletally. Class I had significantly greater maxillary inter-molar, inter-canine, and inter-alveolar widths than class II, division 1. In addition, the class II/1 cases had slightly smaller intermolar widths in the mandible than the control group, but the group differences were not statistically significant.

Staley et al. (289) and Sayin and Tukkahraman (312) stated that the narrow arch widths in class II patients are caused by both palatally tipped teeth and narrow bony bases.

In a meta-analysis study by Lombardo et al. (316) it was concluded that no statistically significant differences in arch widths were found between the different classes (class I and class II div.1, and class II div.2). The mandibular inter-canine width was smaller in class I than in class II div.1. In contrast, the maxillary inter-premolar width was smaller in class II-1 than in class I. They observed that the distance between mandibular canines was smaller in class I than in class II division1; the mandibular inter-molar distance was similar in class I and class II division1; the maxillary inter-canine distance was similar in class I, class II division 2, and class II division1; maxillary inter-premolar width was greater in class I than in class II division 1, and this maxillary inter-molar width was similar in class I and class II division 2.

Recently, Hashim et al. (317) found no significant difference between maxillary variables in class I and class III, in a study of Qatari sample. However, a statistically significant difference in class II maxillary variables (width of second inter-molar, first and second inter-premolar) was noted. Furthermore, significant differences were found in the width of the first and second mandibular inter-molars, and the width of the second inter-premolar between class III and class I malocclusions, and between class III and class II malocclusions. Class III malocclusions showed wider arch dimensions than those of classes I and II.

Very recently, in 2021, in a study of the Nepali population, Yadav et al. (298) noted that the inter-canine arch width in the maxilla was wider in class I and narrower in class II, division 1.

Meanwhile, the inter-molar arch width was narrower in class II, division 1 and wider in class III malocclusion. The inter-canine arch width in the mandible was narrower in class I and wider in class III, while the inter-molar arch width was narrower in class II, division 1 and wider in class III malocclusion.

In a study of Japanese girls (2008), Chen et al. (318) showed that the maxillary intermolar widths were significantly smaller in the class III group than in the class I group. However, the mandibular width showed no significant difference between the groups. The class III subjects had larger molar differences that were statistically significant at 10 to 14 years of age. Hence, in the class III subjects, the deviations in molar differences appear to become larger if not corrected. They concluded that the greatest transverse deficiencies of the class III groups were in both skeletal and dental maxillary widths. The variation in molar differences appeared to be greater between the ages of 10 and 14 years. They also suggested that in various malocclusions, the clinician should observe intermaxillary changes with age and pay attention to discrepancies between the dental arches in the diagnostic process.

Braun et al. (319) found that mandibular arch widths in class III are on average 2.1 mm wider than mandibular arch widths in class I. They suggest that class III arch width may increase because of the tongue's ability to adapt to decreasing arch depths, or because of dental compensation.

According to Patel et al. (320), the disagreements between studies on arch widths in class I, class II, and class III malocclusions can be explained by several factors, including sex dimorphism, ethnic and racial differences, sample selection and size, and subject age.

A clinician should be aware of the relationship between transverse and sagittal anomalies during the diagnostic process of Class II malocclusion, as well as paying attention to transverse inter-arch discrepancies, which may be determined by measuring molar differences or comparable inter-arch discrepancies (137).

Furthermore, the morphological characteristics of the various malocclusions may serve as additional determinants in selecting appropriate treatment options for transverse anomalies and in borderline cases between extraction and non-extraction treatment (137, 318).

In our study, the maxillary arch width dimensions, as a whole, are narrower in adolescents with class II malocclusions than in adolescents with class I and class III malocclusions. Interestingly, the class I and class II groups had similarintercanine width in the mandibular arch, which was in concordance with the study by Staley et al. (289) on an adult sample.

The arch length changes that occur throughout our life span are important to the clinician involved in treating malocclusion. Understanding the changes helps the clinician design an appropriate treatment plan and helps the clinician explain to the patient the changes that may occur during treatment and after retention has ended (141).

In the present study, a significant difference was found in maxillary arch length, where class I had the highest mean, followed by classes III and II. In contrast, mandibular arch length showed no statistically significant differences (Table 33). This was in line with a study of a Pakistani young adult population with class I malocclusion (2015), in which Shahid et al. (29) found statistically significant differences in maxillary arch length but no statistically significant differences in mandibular arch length.

In contrast, Hashim and Al-Gandhi (233) found no significant difference in the arch length between the malocclusion groups and the normal occlusion group in a sample Arab population. In another study involving 53 Malaysian subjects with class I malocclusion (mean age = 25.81), Alam et al. (144) measured arch length in both arches by CBCT 3D acquisition. They found statistically significant differences between excessive mandibular arch length and average arch length in relation to the Bolton overall ratio.

In conclusion, Bishara et al. (130) suggested that regardless of the techniques used to measure arch length, width, or shape, in either a two-dimensional or three-dimensional approach, it is important to remember that the findings from the maxillary and mandibular arches should be related to each other to obtain a more accurate diagnosis of the extent of the malocclusion.

Moreover, the results in the present study also showed a significant difference in the arch perimeter of the maxilla, where class I had the highest average, followed by class III and class II. In contrast, no statistically significant differences in the arch perimeter of the mandible were found between classes of malocclusions (Table 33). Our results differ from a previous study (175), that determined and compared the arch perimeter between the class I normal occlusion and class II malocclusion groups in a study with a Kurdish sample of young adults (100 pretreatment orthodontic models). In contrast, they found that the maxillary and mandibular arch perimeters in class I normal occlusion were significantly shorter than those of class II, division 1, but no significant difference was found compared to the class II, division 2 group. Further, in another study of a young Pakistani adult population with class I malocclusion (2015), Shahid et al. (29) found no statistically significant differences between the maxillary and mandibular arch perimeters. Alam et al. (144) measured the arch perimeter in both arches by CBCT 3D acquisition in a sample of 53 Malaysian subjects with class I malocclusion. They found statistically significant differences between the different arch perimeter groups in relation to the Bolton anterior ratio. However, the samples in these studies did not include class II and class III subjects.

Regarding arch form, our results found a significant difference in the arch form of the mandible, with class III having the highest value, followed by classes II and I. No statistically significant differences were found in the arch form of the maxilla (Table 33). Olmez and Dogan (300) studied 600 Turkish subjects (362 girls and 238 boys) with pretreatment mandibular dental casts, aged between 14 and 19 years, including Angle class I, class II and class III, with 200 subjects each. The facial axis clinical crown points were used as landmarks to identify the mandibular arch forms. They discovered that the tapered arch form was the most common among malocclusion groups (I> II>III), followed by the less common ovoid and square arch forms. According to their study, there was no statistically significant difference in the variance in arch form between classes I and II. The tapered arch form was found frequently in both groups, while the occurrence of the ovoid arch form was lower. The frequency of the square arch form was higher in class III arches. Furthermore, Angle class III had the highest intermolar width and the lowest values of canine and molar depth measurements when the measurements of arch dimension were compared to the Angle malocclusion groups.

Braun et al. (319) found that mandibular arches with class III malocclusion were on average 2.1 mm wider than those with class I malocclusion, when measured from the premolars. This finding was supported by another study by Braun et al. (321), who determined that class II mandibular arches were typically narrower and deeper than class I. Moreover, they observed that class III mandibular arches were shallower than class I by 3.3 mm. These findings suggest that the shape of the mandibular arch is closely related to the degree of malocclusion. In comparison to our results, Nojima et al. (322) found that the differences between the three classes were significant, with class I arches being deeper than class II arches in Caucasian and Japanese subjects, and class III arches being shallower and wider than those of classes I and II. On the other hand, other studies performed by some investigators reported that both canine and molar W/D ratios are the lowest in class II arches, followed by classes I and III (322-324).

Regarding the arch depth, Morreess (325) reported that between mixed and permanent dentition, the arch depth decreases by about 0.5 mm more in the mandible than in the maxilla. Moreover, it decreases at a similar rate in the maxilla and the mandible (135). In their study, Brown and Jensen (140) found that in the non-treated group (24 casts in each series), a decrease in bite depth occurred in 17 casts, or 70.8% (more than two-thirds of the group). The decreased range was from 0.05 to 1.95 mm, with a mean of .78 mm.

The results obtained from our study only found a significant difference in maxillary arch depth between the three malocclusion classes, with class III having the highest value, followed by classes I and II (Table 33).

In contrast, Ahmed and Fida (305) in their study of 110 Pakistani subjects (mean age = 17.4 years) with different malocclusion groups, discovered no significant differences in maxillary and mandibular arch depth among the three malocclusion groups. However, a comparison between class I and class III showed that the mean maxillary arch depth was greater in class I than in the class III group.

According to Cassidy et al. (326) in their genetic study, the difference in arch depth between the skeletal group and the three modern groups was greater in the maxilla than in the mandible or in the transverse dimensions. They found that heritability was lower for maxillary arch depth than for mandibular arch depth or arch width. They concluded that arch size had a modest genetic component.

The present study also showed significant differences in the index of incisal irregularities in three groups of malocclusions in both jaws. According to the results, subjects with class III malocclusion had the greatest values for irregularity of the maxillary and mandibular incisors, followed by classes II and I (Table 32).

However, it should be noted that, due to the limited number of class III subjects, the data presented should be interpreted with caution. Obviously, it would have been very beneficial to include more Class III subjects in our study. Unfortunately, the prevalence of class III in the population is known to be lower than that of class I or class II, and it has been difficult to find untreated class III subjects.

Buschang et al. (110) showed that adult females with class II malocclusion had more upper incisor irregularities and fewer lower incisor irregularities than females with class I malocclusion. Meanwhile, Ghaib et al. (286) found that male subjects with a class II malocclusion had more upper incisor irregularities, while female subjects with a class I malocclusion had a higher prevalence of crowded lower incisors.

The results of our study found a significant difference in overjet, precisely in class II, which had the highest average value (Table 32). This is in line with the study by Staley et al. (289), in which the class II subjects had significantly greater overjet than subjects with normal occlusion.

The results obtained in our study also showed significant differences of overbite among the classes. Class II showed significantly higher overbite values than classes I and class III (Table 32). Due to the lack of comparative research in the literature, the results obtained were very difficult to compare.

In any case, overbite represents an important component of dental occlusion that merits more research to improve our understanding of its behavior during the developmental years, especially in the years when orthodontic treatment is often recommended (117).

Within the palatal dimensions, our results showed significant differences in the three malocclusion groups. In the present study, the width of the palate was greater in class I, followed by classes II and III (Table 33). This was in line with a study of an adult Iraqi population (200) which found that the class I had the largest palatal width, followed by classes II and III, but with a non-significant difference. In the study of a Yemeni adult population with class I malocclusion (199), the width of the palate was 40.4±2.55.

In the present study, palatal length was higher in class III, followed by classes I and II (Table 34). In contrast, Nahidh et al. (200), in a study of an adult Iraqi Arab population, found that class II palatal length was greater than in other classes, followed by classes I and III, with a very highly significant difference, as indicated by the ANOVA test. On the other hand, Al-Zubair et al. (199) in a study of an adult Yemeni population with class I malocclusion found that the palatine length was 30.05±2.03.

Our study's results showed that palatal height was higher in class III, followed by classes I and II (Table 33). This was not in line with a study by Nahidh et al. (200), which showed that class I had the largest palatal height, followed by classes II and III with a non-significant difference. Nevertheless, in a study of a Saudi Arabian population, Al-Shahrani et al. (327) found no significant relationship between Angle class I, II, and III malocclusions regarding palatal height.

However, other authors also reported differences in palatal height between class I and III malocclusions, and in palatal dimensions between different types of malocclusion (189, 328). In the research of a Yemeni population with normal class I malocclusions (199), the height of the palate was found to be 21.0±1.5mm.

Within the palatal height index, the results of the present study showed no significant differences among classes. In some cases, however, differences were found, e.g. males had the highest value in class III, while females had the highest value in class II (Table 33).

Different races, ethnicities and populations have different palate shapes and depths. Our study found that 97.5% of Kosovar adolescents had shallow palates based on the palate height index. Further, 2.3% of Kosovars had high palates, while 0.3% had average palates (Table 34). On the other hand, Zaaba and Jain (301) compared two Malaysian and Indian populations. Indians and Malaysians have low palates at 50% and 67% respectively. Medium palates were found in 33% of Indians and 20% of Malaysians; high palates were found in 20% of Indians and 13% of Malaysians.

Along with Redman et al. (192), Knott and Johnson (193), also reported differences in palatal height index values. Despite physical differences between American and Australian children, different reference points may also account for variations in the results. Compared to this study, the Redman, Shapiro and Gorlin indices were smaller (192). They chose to measure the height of the palate at the junction of the hard and soft palates to avoid palatine tori. The palate index values in this region were lower because it is not the deepest part of the palate. Knott and Johnson (193) made measurements between the lingual gingival margins and obtained smaller width values and larger palatal index values than this study, in which the measurements were taken between the opposing interdental papillae.

An Australian study by Howell (329) found no statistically significant difference in P.I. between deciduous and permanent dentition. However, she used different point references than we did. In contrast, Redman, Shapiro and Gorlin (192) published data collected directly from a sample of Minnesota schoolchildren and pediatric dental patients based on palatal measurements taken directly in the mouth. As "height" is defined differently between the two studies, the indices of the height-width relationship are not directly comparable (193). The differences in measuring palatal height between investigators may be attributed to their selection of reference plane and measurement points on the palatal vault (192, 193).

Overall, our study provided evidence supporting our objective and hypothesis that dental arch dimensions differ significantly in relation to malocclusion. However, it’s important to note that our study had certain limitations, such as a limited sample size of class III subjects. This may have affected the generalizability of the results. Additionally, we could not control for the effects of other factors, such as genetics, that may also contribute to dental arch dimensions. Finally, our study was cross-sectional in design, so we could not draw conclusions about cause and effect. However, further research is needed to better understand the potential effects of malocclusion classes on dental arch dimensions. Longitudinal studies are needed to assess the relationship between these variables.

6. CONCLUSIONS

This study confirmed significant differences between males and females for all teeth dimensions in terms of MD, BL, MBDL, MLDB diagonal crown widths and crown height on both arches, with males exhibiting larger crown dimensions than females. Further investigation of this notable sexual dimorphism in dental crown measurements may shed light on the factors contributing to these disparities. Such distinctions between males and females in dental dimensions carry significant implications for clinical practices, particularly in orthodontics, where a more tailored and sex-specific approach may be warranted.

Furthermore, the findings of the study also indicate significant differences between malocclusion classes and the MD widths, diagonal crown width MLDB, and crown height of maxillary teeth and mandibular teeth. In contrast, the majority of teeth showed no significant differences in BL width and diagonal crown width MBDL measurements between the malocclusion groups. By understanding these variations, orthodontic professionals can tailor their diagnostic and treatment strategies to address the unique needs of patients within different categories of malocclusion. Importantly, this exploration highlights the nuanced nature of dental health. As such, it illustrates the importance of acknowledging the individualized factors at play when assessing dental issues.

In summary, the study confirmed the objective and hypothesis related to tooth size dimensions by revealing significant sexual dimorphism and variations in tooth size among different malocclusion groups in the Kosovar population. These findings are valuable for orthodontic diagnosis and treatment planning.

No statistically significant sex differences in tooth size ratios among Kosovar adolescents were found. Accordingly, this indicates that sex differences in tooth size ratios are not significant in this population.

Moreover, there were statistically significant sex differences in UII and LII, while no statistically significant sex differences were found in overjet and overbite values among Kosovar adolescents. Sex-specific treatments may be needed to correct UII and LII differences. Therefore, considering sex-related factors is essential in providing orthodontic care to adolescents.

In addition, there were statistically significant sex differences in dental arch dimensions between male and female Kosovar adolescents, except for the mandible arch form and palatal height index. In general, male arch dimensions were larger than females, with the exception of the maxillary arch form, which was larger in females. The results indicate that sex can influence dental arch dimensions in Kosovar adolescents.

In summary, this study successfully fulfills its objectives and confirmed its initial hypothesis by revealing clear sexual dimorphisms in numerous dental arch dimensions and the palatal height index. However, it's essential to acknowledge that not all dental parameters exhibited sexual dimorphism, as demonstrated by the lack of significant differences in Bolton's tooth size ratios. Such nuanced outcomes are common in scientific research, and highlight the complexity and diversity of human biology and genetics. This study emphasizes the necessity of adopting a multifaceted and personalized approach to dental care that takes into account individual factors, sex-specific variations, and the unique characteristics of diverse populations.

Moreover, the findings vary from Bolton's original study regarding tooth size ratios in Kosovar adolescent population. Notably, the anterior tooth size ratio in Kosovars was 79.81 percent, higher than the value established by Bolton (77.2 percent). This suggests that the Kosovar population may exhibit different tooth size ratios, particularly in the anterior segment, emphasizing the significance of considering population-specific criteria in orthodontic practice. Likewise, the study revealed a higher average overall tooth size ratio of 92.89 percent in the Kosovar population, compared to Bolton's 91.3 percent. In terms of overall and posterior ratios, there were no significant differences between malocclusion classes, suggesting that malocclusion primarily influences anterior tooth size ratios.

Intriguingly, the study reported a relatively high prevalence of significant tooth size discrepancies (more than 2 SD) in the anterior (41.37 percent) and overall ratios (23.79 percent) in the Kosovar population. This emphasizes the importance of considering individualized criteria for clinical diagnosis. The study underscores the need for clinicians to be aware of the frequent occurrence of tooth size discrepancies when assessing and treating orthodontic patients, particularly in the anterior segment. The prevalence of Bolton discrepancies may differ between populations with different occlusal disorders, which supports the hypothesis that population-specific variations exist.

Bolton original values may not be representative of the Kosovar population and should not be used for orthodontic diagnosis and treatment. The study highlights the importance of conducting Bolton's analysis routinely for orthodontic patients, regardless of malocclusion, sex, or population.

In summary, the findings from this study confirm the hypothesis that there are differences in the incidence of tooth size discrepancies among different malocclusion groups within the Kosovar schoolchildren population. The study demonstrates that anterior tooth size ratios in the Kosovar population are higher than those observed in Bolton's original sample, indicating population-specific variations. Furthermore, the study highlights the importance of considering population-specific criteria in clinical orthodontic diagnosis and treatment.

Additionally, the research extends its reach to encompass the role of malocclusion in the dental health of Kosovar adolescents. It reveals significant statistically differences between malocclusion classes and UII, overjet and overbite among Kosovar adolescents, underlining the importance of recognizing the influence of malocclusion on these specific dental parameters. However, no significant difference was found for LII, suggesting the need for more in-depth investigation into this aspect of dental health.

Expanding further, the study probes into the broader landscape of dental arch dimensions, uncovering a host of compelling insights. Notably, statistically significant differences were found between malocclusion classes in terms of maxillary arch widths, maxillary arch length, maxillary arch perimeter, maxillary arch depth, and palatal length among Kosovar adolescents. Specifically, class I malocclusion showed the highest value, followed by classes II and III.

Our study found that most Kosovar adolescents had square arches (58%), followed by tapered arches (26%) and oval arches (16%). These results shed light on the intricate relationship between malocclusion and dental arch dimensions, offering valuable information for orthodontic diagnosis and treatment planning. Therefore, it can be concluded that malocclusion classes have distinct arch features among Kosovar adolescents.

No statistically significant differences of the palatal height index were detected among the various malocclusion classes. This suggests that not all aspects of the palatal dimensions were significantly affected by malocclusion. However, the study suggests that the palatal height index is a reliable measure of malocclusion severity. Our study found that 97.5% of Kosovar adolescents had shallow palates based on the palate height index. Further, 2.3% of Kosovars had high palates, while 0.3% had average palates.

In a comprehensive summary, the findings from this study largely confirm the stated objectives and hypothesis that dental arch dimensions differ significantly in relation to different malocclusion classes. The study's results provide evidence of these differences in various aspects of dental arch dimensions. However, it's important to acknowledge the study's limitations, such as the limited sample size of class III subjects and the cross-sectional design, which may have some impact on the generalizability and causative conclusions. Further research, including longitudinal studies, is suggested to gain a more comprehensive understanding of these relationships.

In a broader context, this study convey a crucial message about the importance of recognizing sex-specific variations in the field of orthodontic and dental treatment planning. This awareness extends to considering the unique characteristics of each person's dental arch, underscoring the importance of a more tailored approach to dental health. By contributing to the growing body of knowledge in this field, the research enriches our collective understanding of dental characteristics accross various populations.

This study serves as thorough exploration of dental health, unearthing valuable insights and shedding light on the intricate details of various dental dimensions, tooth size ratios, and arch measurements. These findings will greatly benefit the fields of orthodontics and dental treatment planning, enabling the devilery of more effective and personalized care to individuals in the Kosovar population and beyond.

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8. APPENDIX A

APPENDIX A: Supplementary data

In the following supplementary files, tables (1-8) provide the results of the reliability measurements conducted on 30 dental casts.

Table 1. Results of MD width (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
Tooth	**M1**	**M2**	**M1**	**M2**					
Maxilla									
11	8.75	8.56	0.55	0.47	0.18	-0.07	0.45	0.16	0.18
12	6.70	6.46	0.53	0.53	0.23	-0.03	0.51	0.088	0.23
13	8.00	7.80	0.40	0.40	0.20	-0.00	0.40	0.058	0.20
14	7.06	6.83	0.48	0.39	0.23	0.00	0.45	0.048	0.23
15	6.65	6.40	0.42	0.40	0.25	0.03	0.46	0.021	0.25
16	9.93	9.69	0.47	0.52	0.23	-0.02	0.49	0.079	0.23
17	9.44	9.25	0.55	0.53	0.19	-0.08	0.47	0.177	0.19
21	8.77	8.56	0.52	0.51	0.21	-0.05	0.48	0.119	0.21
22	6.71	6.46	0.51	0.55	0.25	-0.02	0.53	0.073	0.25
23	8.04	7.78	0.48	0.40	0.25	0.02	0.48	0.033	0.25
24	6.98	7.02	0.45	0.45	0.21	-0.01	0.44	0.062	0.21
25	6.59	6.31	0.41	0.36	0.27	0.07	0.47	0.007	0.27
26	10.02	9.80	0.47	0.51	0.22	-0.03	0.47	0.089	0.22
27	9.52	9.36	0.47	0.47	0.16	-0.08	0.40	0.192	0.16
Mandible									
31	5.90	5.66	0.32	0.39	0.23	0.05	0.42	0.014	0.23
32	6.47	6.16	0.34	0.44	0.30	0.09	0.51	0.005	0.30
33	7.42	7.14	0.53	0.58	0.28	-0.00	0.57	0.055	0.28
34	7.33	7.11	0.61	0.57	0.22	-0.08	0.53	0.146	0.22
35	7.38	7.08	0.58	0.53	0.29	0.00	0.58	0.050	0.29
36	11.09	10.78	0.70	0.67	0.31	-0.04	0.67	0.083	0.31
37	10.07	9.95	0.61	0.55	0.12	-0.17	0.42	0.419	0.12
41	5.83	5.63	0.35	0.41	0.20	0.00	0.40	0.048	0.20
42	6.30	6.07	0.31	0.36	0.23	0.05	0.40	0.010	0.23
43	7.28	7.00	0.40	0.43	0.27	0.06	0.49	0.012	0.27
44	7.30	7.06	0.54	0.56	0.23	-0.05	0.52	0.111	0.23
45	7.27	7.02	0.51	0.57	0.24	-0.04	0.52	0.090	0.24
46	11.18	10.84	0.72	0.77	0.34	-0.04	0.73	0.079	0.34
47	10.31	10.09	0.55	0.48	0.21	-0.05	0.48	0.111	0.21

Table 2. Results of BL width (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
Tooth	**M1**	**M2**	**M1**	**M2**					
Maxilla									
11	7.66	7.68	0.496	0.48	-0.01	-0.27	0.23	0.87	-0.01
12	6.81	6.81	0.61	0.59	0.00	-0.30	0.31	0.96	0.00
13	8.54	8.53	0.54	0.52	0.00	-0.26	0.28	0.96	0.01
14	9.57	9.58	0.42	0.41	-0.01	-0.22	0.20	0.91	-0.01
15	9.68	9.71	0.52	0.49	-0.03	-0.29	0.23	0.82	-0.03
16	11.15	11.17	0.56	0.56	-0.01	-0.31	0.27	0.89	-0.01
17	11.00	11.03	0.79	0.71	-0.02	-0.41	0.36	0.88	-0.02
21	7.66	7.65	0.49	0.57	0.00	-0.27	0.28	0.97	0.01
22	6.88	6.90	0.54	0.50	-0.02	-0.29	0.25	0.87	-0.02
23	8.51	8.58	0.57	0.56	-0.06	-0.35	0.22	0.66	-0.06
24	9.49	9.49	0.44	0.41	-0.00	-0.22	0.21	0.95	0.00
25	9.63	9.61	0.55	0.62	0.02	-0.28	0.32	0.89	0.02
26	11.07	11.13	0.53	0.52	-0.06	-0.33	0.20	0.63	-0.06
27	10.89	10.94	0.63	0.66	-0.04	-0.38	0.28	0.78	-0.04
Mandible									
31	6.36	6.39	0.41	0.36	-0.02	-0.22	0.17	0.80	-0.02
32	6.73	6.72	0.53	0.41	0.00	-0.24	0.25	0.95	0.00
33	7.82	7.89	0.69	0.57	-0.07	-0.40	0.25	0.66	-0.07
34	8.22	8.18	0.53	0.52	0.04	-0.23	0.31	0.75	0.04
35	8.75	8.78	0.48	0.52	-0.02	-0.29	0.23	0.82	-0.02
36	10.58	10.64	0.43	0.43	-0.05	-0.27	0.16	0.62	-0.05
37	10.16	10.34	0.49	0.47	-0.18	-0.43	0.06	0.14	-0.18
41	6.35	6.36	0.43	0.38	-0.00	-0.22	0.20	0.93	-0.00
42	6.63	6.64	0.46	0.44	-0.01	-0.24	0.22	0.91	-0.01
43	7.74	7.80	0.64	0.64	-0.05	-0.39	0.27	0.74	-0.05
44	8.28	8.32	0.56	0.50	-0.03	-0.31	0.24	0.78	-0.03
45	8.89	8.92	0.55	0.47	-0.03	-0.29	0.23	0.81	-0.03
46	10.71	10.73	0.34	0.33	-0.02	-0.19	0.15	0.81	-0.02
47	10.12	10.22	0.55	0.51	-0.10	-0.38	0.17	0.45	-0.10

Table 3. Descriptive statistics of MBDL width (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
Tooth	M1	M2	M1	M2					
Maxilla									
11	9.50	9.39	0.56	0.54	0.10	-0.18	0.38	0.47	0.10
12	7.51	7.47	0.51	0.49	0.03	-0.22	0.29	0.76	0.04
13	7.90	7.85	0.55	0.56	0.04	-0.24	0.33	0.74	0.05
14	7.67	7.76	0.34	0.39	-0.08	-0.27	0.10	0.37	-0.08
15	7.73	7.97	0.39	0.33	-0.24	-0.43	-0.05	0.01	-0.25
16	11.57	11.64	0.56	0.59	-0.07	-0.37	0.22	0.63	-0.07
17	10.45	10.63	0.94	0.90	-0.18	-0.65	0.29	0.45	-0.18
21	9.48	9.41	0.50	0.38	0.06	-0.16	0.29	0.54	0.07
22	7.65	7.64	0.48	0.47	0.01	-0.23	0.25	0.92	0.01
23	7.89	7.79	0.59	0.62	0.09	-0.22	0.41	0.54	0.10
24	7.45	7.59	0.41	0.43	-0.14	-0.36	0.07	0.19	-0.14
25	7.48	7.65	0.35	0.35	-0.17	-0.35	0.00	0.06	-0.17
26	11.58	11.66	0.59	0.63	-0.07	-0.39	0.23	0.62	-0.08
27	10.35	10.43	0.92	0.95	-0.07	-0.56	0.40	0.75	-0.08
Mandible									
31	7.20	7.09	0.52	0.63	0.10	-0.19	0.40	0.47	0.11
32	7.33	7.26	0.56	0.61	0.06	-0.23	0.37	0.65	0.07
33	7.55	7.56	0.67	0.56	-0.01	-0.33	0.30	0.93	-0.01
34	7.13	7.22	0.33	0.42	-0.08	-0.28	0.10	0.37	-0.09
35	7.44	7.58	0.52	0.51	-0.14	-0.41	0.12	0.28	-0.14
36	10.66	10.64	0.56	0.65	0.02	-0.29	0.33	0.89	0.02
37	10.05	10.13	0.54	0.53	-0.08	-0.35	0.19	0.56	-0.08
41	7.28	7.33	0.65	0.80	-0.04	-0.42	0.33	0.80	-0.05
42	7.48	7.43	0.63	0.52	0.04	-0.25	0.35	0.74	0.05
43	7.74	7.61	0.57	0.56	0.13	-0.15	0.43	0.36	0.14
44	7.01	7.12	0.46	0.50	-0.11	-0.36	0.14	0.38	-0.11
45	7.40	7.39	0.50	0.60	0.01	-0.27	0.29	0.93	0.01
46	10.85	10.86	0.50	0.56	-0.00	-0.28	0.26	0.94	-0.01
47	10.28	10.19	0.56	0.65	0.08	-0.22	0.40	0.57	0.09

Table 4. Descriptive statistics of MLDB width (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
Tooth	M1	M2	M1	M2					
Maxilla									
11	8.65	8.52	0.54	0.63	0.13	-0.17	0.43	0.39	0.13
12	7.00	6.96	0.58	0.54	0.03	-0.25	0.33	0.78	0.04
13	7.58	7.60	0.51	0.43	-0.02	-0.26	0.22	0.85	-0.02
14	7.95	8.08	0.42	0.46	-0.13	-0.36	0.09	0.24	-0.14
15	7.82	8.03	0.40	0.55	-0.21	-0.46	0.03	0.09	-0.21
16	9.86	10.26	0.59	0.54	-0.39	-0.69	-0.10	0.00	-0.40
17	9.12	9.53	0.63	0.60	-0.41	-0.73	-0.09	0.01	-0.42
21	8.56	8.47	0.44	0.65	0.08	-0.20	0.37	0.55	0.09
22	6.83	6.84	0.52	0.54	-0.00	-0.28	0.27	0.95	-0.01
23	7.45	7.38	0.49	0.52	0.06	-0.19	0.33	0.62	0.07
24	8.05	8.22	0.47	0.44	-0.17	-0.40	0.06	0.15	-0.17
25	8.05	8.18	0.47	0.60	-0.12	-0.40	0.15	0.37	-0.13
26	9.99	10.22	0.63	0.50	-0.23	-0.52	0.06	0.12	-0.23
27	9.27	9.52	0.68	0.57	-0.25	-0.58	0.06	0.12	-0.26
Mandible									
31	7.25	7.20	0.56	0.54	0.05	-0.23	0.34	0.70	0.06
32	7.29	7.15	0.55	0.47	0.13	-0.12	0.40	0.29	0.14
33	6.93	6.88	0.57	0.48	0.04	-0.23	0.31	0.74	0.04
34	6.61	6.72	0.50	0.41	-0.11	-0.35	0.12	0.35	-0.11
35	7.41	7.50	0.48	0.46	-0.08	-0.32	0.16	0.51	-0.08
36	10.64	10.65	0.54	0.56	-0.01	-0.29	0.27	0.94	-0.01
37	10.11	10.28	0.52	0.55	-0.17	-0.45	0.10	0.22	-0.17
41	7.15	7.08	0.50	0.40	0.06	-0.17	0.30	0.57	0.07
42	7.06	6.94	0.58	0.55	0.12	-0.17	0.41	0.41	0.12
43	6.86	6.67	0.68	0.47	0.18	-0.12	0.48	0.23	0.18
44	6.58	6.62	0.42	0.37	-0.04	-0.25	0.16	0.65	-0.05
45	7.39	7.46	0.50	0.40	-0.06	-0.30	0.16	0.56	-0.07
46	10.44	10.65	0.54	0.53	-0.20	-0.48	0.06	0.13	-0.21
47	10.05	9.98	0.58	0.62	0.07	-0.24	0.38	0.65	0.07

Table 5. Descriptive statistics of crown height (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
Tooth	M1	M2	M1	M2					
Maxilla									
11	9.31	9.27	1.03	1.05	0.03	-0.50	0.57	0.89	0.04
12	7.53	7.53	0.95	0.94	-0.02	-0.51	0.46	0.91	0.00
13	8.69	8.63	0.91	0.95	0.05	-0.43	0.53	0.82	0.05
14	7.11	7.17	0.76	0.76	-0.05	-0.45	0.33	0.76	-0.06
15	6.24	6.25	0.81	0.84	-0.00	-0.43	0.42	0.97	-0.01
16	5.23	5.29	0.68	0.61	-0.05	-0.39	0.27	0.72	-0.06
17	4.61	4.63	0.87	0.91	-0.01	-0.47	0.44	0.94	-0.01
21	9.35	9.39	0.94	0.97	-0.04	-0.53	0.45	0.87	-0.04
22	7.65	7.64	0.80	0.79	0.00	-0.40	0.42	0.97	0.01
23	8.66	8.60	0.87	0.88	0.05	-0.39	0.50	0.81	0.05
24	7.20	7.15	0.64	0.60	0.04	-0.27	0.37	0.75	0.05
25	6.26	6.20	0.83	0.71	0.05	-0.34	0.45	0.78	0.05
26	5.07	5.05	0.66	0.63	0.01	-0.32	0.35	0.92	0.02
27	4.61	4.52	0.67	0.65	0.08	-0.25	0.43	0.61	0.09
Mandible									
31	7.82	7.89	0.68	0.79	-0.06	-0.45	0.31	0.72	-0.07
32	7.88	7.93	0.65	0.69	-0.05	-0.40	0.29	0.76	-0.05
33	9.00	8.95	0.93	0.96	0.05	-0.44	0.54	0.83	0.05
34	7.73	7.76	0.65	0.62	-0.02	-0.35	0.30	0.87	-0.03
35	6.82	6.88	0.62	0.60	-0.06	-0.37	0.25	0.70	-0.06
36	6.07	6.31	0.50	0.42	-0.23	-0.47	0.00	0.05	-0.24
37	4.92	5.22	0.64	0.56	-0.29	-0.61	0.01	0.06	-0.30
41	7.75	7.80	0.70	0.72	-0.05	-0.42	0.31	0.77	-0.05
42	7.81	7.82	0.75	0.79	-0.00	-0.40	0.39	0.96	-0.01
43	9.13	9.10	1.06	1.07	0.02	-0.52	0.57	0.92	0.03
44	7.72	7.73	0.59	0.65	-0.01	-0.33	0.31	0.94	-0.01
45	7.04	7.06	0.80	0.86	-0.02	-0.45	0.41	0.92	-0.02
46	6.17	6.35	0.50	0.50	-0.17	-0.43	0.08	0.18	-0.18
47	4.78	5.02	0.55	0.68	-0.23	-0.56	0.08	0.14	-0.24

Table 6. Descriptive statistics of tooth size ratio and TSDs (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
	M1	M2	M1	M2					
Anterior ratio	79.93	79.46	2.81	2.82	0.47	-0.98	1.93	0.51	0.47
Overall ratio	92.46	92.48	2.32	2.25	-0.19	-1.37	0.99	0.74	-0.19
Posterior ratio	105.47	106.20	3.54	3.50	-0.72	-2.54	1.09	0.42	-0.72
Anterior discrepancy	-1.55	-1.29	1.77	1.64	-0.26	-1.01	1.33	0.55	-0.26
Posterior discrepancy	-1.36	-1.52	2.32	2.21	0.15	-1.01	1.33	0.79	0.15

Table 7. Descriptive statistics of occlusal parameters (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
	M1	M2	M1	M2					
Little's Incisal irregularity index									
Maxilla	3.43	3.34	1.60	1.53	0.09	-0.72	0.90	0.82	0.09
Mandible	2.06	1.87	0.59	0.57	0.19	-0.11	0.49	0.21	0.19
Overjet									
Overjet	2.76	2.88	1.11	1.05	-0.11	-0.67	0.44	0.68	-0.11
Overbite									
Overbite	3.58	3.74	1.01	1.01	-0.15	-0.68	0.36	0.55	-0.15

Table 8. Descriptive statistics of dental arch dimensions (n=30)

Dental arch dimensions		**Mean**		**SD**		**Mean difference**	**Lower**	**Upper**	**P-value**	**Dahlberg's error**
		M1	**M2**	**M1**	**M2**					
Arch width maxilla	C-C	34.91	35.02	2.13	2.07	-0.11	0.54	-1.20	0.83	-0.11
	P_1-P_1	42.21	42.22	2.23	2.17	-0.01	0.57	-1.14	0.98	-0.00
	P_2-P_2	47.49	47.65	2.55	2.37	-0.15	0.63	-1.42	0.81	-0.15
	M_1-M_1	52.21	52.43	2.49	2.36	-0.22	0.62	-1.47	0.72	-0.22
Arch width mandible	C-C	26.39	26.55	1.40	1.56	-0.16	0.38	-0.93	0.67	-0.16
	P_1-P_1	34.83	34.96	1.42	1.41	-0.12	0.36	-0.85	0.73	-0.13
	P_2-P_2	40.39	40.51	2.06	1.97	-0.12	0.52	-1.16	0.81	-0.12
	M_1-M_1	45.38	45.47	2.18	2.20	-0.09	0.56	-1.22	0.86	-0.09
Arch length	Arch length maxilla	129.21	129.70	5.81	5.78	-0.49	-3.49	2.50	0.74	-0.49
	Arch length mandible	111.99	112.42	4.75	4.63	-0.42	-2.84	2.00	0.73	-0.43
Arch perimeter	Arch perimeter maxilla	93.34	93.77	4.82	3.77	-0.43	-2.67	1.81	0.70	-0.43
	Arch perimeter mandible	85.16	85.72	3.70	3.45	-0.55	-2.41	1.29	0.54	-0.56
Arch form	Arch form maxilla	1.43	1.43	0.77	0.77	0.00	-0.40	0.40	1.00	0.00
	Arch form mandible	1.97	2.20	0.85	0.71	-0.23	-0.63	0.17	0.25	-0.23
Arch depth	Arch depth maxilla	30.14	30.30	2.18	2.00	-0.16	-1.24	0.92	0.76	-0.16
	Arch depth mandible	25.21	26.71	2.49	2.00	-1.50	-2.67	-0.33	0.01	-1.50
Palatal dimensions	Width of palate	35.48	35.38	2.19	2.22	0.10	-1.04	1.24	0.86	0.10
	Length of palate	33.28	33.70	2.68	2.38	-0.42	-1.73	0.89	0.52	-0.42
	Height of the palate	12.10	11.50	2.24	2.06	0.60	-0.51	1.71	0.28	0.60
	Palatal height index	30.53	29.45	4.59	4.49	1.08	-1.26	3.43	0.36	1.08

9. CURRICULUM VITAE

Blertë Zylfiu-Latifi was born on March 12th 1989 in Gjilan, Kosovo. She graduated from the Faculty of Medicine-Department of Dentistry, of the University of Prishtina " Hasan Prishtina", Republic of Kosovo in 2014, attaining the title of Doctor of Dental Medicine.

Since October 2016 she has been employed as a dentist in a private dental clinic in Kamenica. From January 2018 to October 2021 she worked as a dentist in a private dental clinic in Prishtina, Kosovo. In October 2018 she started her PhD studies at the School of Dental Medicine, University of Zagreb, Croatia. In November 2020 she started her orthodontic residency at the Department of Orthodontics, University Dental Clinical Centre in Prishtina, Kosovo.

As an author and co-author of scientific posters and oral presentations, she has participated passively and actively in numerous scientific conferences and published a few research articles in international journals. She is a member of the Dental Chamber of Kosovo.

List of published scientific articles:

1. **Zylfiu-Latifi B,** Kamberi B, Meštrović S. The Occlusal Characteristics of Kosovar Adolescents. International Journal of Biomedicine. 2023; 13(2):281–285. https://doi:10.21103 /Article13(2)_OA15. **Q4** (WoS, Scopus) (Doctoral thesis-related paper)

2. **Zylfiu-Latifi B,** Kamberi B, Meštrović S. Tooth size discrepancies in Kosovar adolescents with different malocclusion classes. Anthropological Review. 2023; 86(2): 27–38. https://doi.org/10.18778/1898-6773.86.2.03. **Q3** (WoS, Scopus) (Doctoral thesis-related paper)

Abstracts and oral presentations in books of abstracts :

1. **Zylfiu-Latifi B**, Morina E. Practices of Kosovar Dentists about Oral Cancer. IDC Prishtinë, 2022; Book of abstracts, 12-13. (Oral presentation)

2. Morina E, **Zylfiu-Latifi B**. A comprehensive and aesthetic rehabilitation for a phobic patient: Case report. IDC Prishtinë, 2022; Book of abstracts, 16-17. (Poster)

3. **Zylfiu B,** Latifi O. Kosovo Dentist Opinions around Oral Cancer. FBCOMF Tiranë, 2022. (Oral presentation)

4. Latifi O, **Zylfiu B.** The treatment of gingival hyperplasia in a patient with periodontal and systemic diseases. A Case Report. SICOSI, 2020. Poster Abstract Book. Skopje, 2020; 41-41. (Poster)