ORIGINAL ARTICLE

KOREAN J ORTHOD
2004;34(6):473-80

Tooth size and arch parameters of normal occlusion in a large Korean sample

Shin-Jae Lee, DDS, MSD, PhD,[a] **Seong-Cheol Moon**, DDS, MSD, PhD,[b] **Tae-Woo Kim**, DDS, MSD, PhD,[c]
Dong-Seok Nahm, DDS, MSD, PhD,[d] **Young-Il Chang**, DDS, MSD, PhD[d]

The aim of this study was to establish normative data on the tooth size and arch parameters of Koreans with normal occlusion. This study employed the dental casts of 296 (male: 179; female 117) normal occlusion samples, who were selected from 15,836 adults through a community dental health survey. The mesiodistal diameters of teeth, arch width, and arch length were measured by digital electronic calipers (accurate to 0.01 mm) and Bolton's indices as well as intermaxillary arch width ratios were calculated. In order to ensure reliability, intra- and inter-examiner error were evaluated. Although our dimensional data showed overt differences between genders, the indices and intermaxillary ratios evaluated were the same. The resultant data obtained were compared with the previous data to reveal whether any changes have occurred over the time. The clinical implication of the present findings was also discussed. This biometric study seemed to provide a clinically applicable diagnostic criteria for an individual malocclusion patient.

Key words : Tooth size, Arch width, Normative data

Dental cast analysis is important because tooth size imbalances can complicate harmonious intercuspation. These imbalances can be detected and readily considered if proper tooth size analysis is accomplished during the initial diagnosis and treatment planning. During the finishing stage, the maxillary or mandibular incisors are often approximated in order to resolve tooth size imbalances. Sometimes, tooth size imbalances often justify the extraction treatment modality. The use of rapid palatal expansion or surgical aids are also determined after an incongruent arch width is found. Therefore, the utmost importance of dental cast analysis should not be underestimated from the initial to the finishing stage of orthodontic treatment.

Considerate case analysis for a malocclusion patient requires reliable reference data which is extracted from samples with normal occlusion. However, if the

Department of Orthodontics, College of Dentistry, Seoul National University, Seoul, Korea
[a] Assistant Professor, [b] Guest Professor, [c] Associate Professor, [d] Professor

Received September 16, 2004; Last Revision October 20, 2004; Accepted November 6, 2004
Reprint requests: **Young-Il Chang**
28-2 Yungeon-Dong, Chongro-Gu, Seoul 110-749, Korea
Department of Orthodontics, College of Dentistry, Seoul National University
+82 2 2072 2600 / drchang@plaza.snu.ac.kr

normative data originated from another, nonidentical population, the case analysis would inevitably be a misinterpreted one. There are various normative data available for the Korean population, however, some were extracted from overseas data, some from small sample sizes, or others from a group of sereral decades ago. No published data were a reliability which dealt a reliability of normative data for Koreans. In the analysis of tooth size and arch parameters, there are well known differences between the ethnic groups. Contemponary data was also emphasized because an environmental factor, such as life style and improved nutrition is known to affect human tooth size and dental arch dimension.[1,2]

Thus, the aim of this biometric study was to establish a normative data on the tooth size and arch parameters, with the normal occlusion samples selected from current Korean adults. In order to minimize random error and ensure reliability of the data, meticulous measurement design was considered and the descriptive statistics and inferential findings were discussed.

MATERIALS AND METHODS

Selection of normal occlusion samples

Two-hundred-ninety-six normal occlusion samples were selected from 15,836 adults through a community dental health survey, from the year 1999 to 2002, in Seoul, Korea. These subjects consisted of 179 male and 117 female individuals with a mean age of 20.0 years. The selection criteria of these normal occlusion samples and their cephalometric characteristics have been previously described by Kim et al.[3]

Examiners

Two investigators measured the linear measurements and the mean data was used in the analysis. Before the full-scale measurements, a three-weeks training period was required until their intra- and inter-examiner reliability coefficients could reach up to 0.995. Three months after the full-scale measurements, in order to evaluate random errors of intra- and inter-examiners, 80 casts were randomly selected and measured twice.

Methods

Evaluations of the tooth size and arch parameters were divided into three investigation categories: (1) mesiodistal diameters of teeth, (2) basal and dental arch width and length, and (3) ratio variables and indices, such as intermaxillary arch width ratio and Bolton's indices.[4,5] A digital Vernier caliper with sharpened points (Mitutoyo Co., Kawasaki, Kanakawa, Japan) was used to measure the tooth size and arch width between all the posterior teeth, including the canines and up to the second molars. A centroid was constructed for each cusp tip, which was relatively independent of cusp wear or abrasion and sensitive to both coronal translation and tipping.

Statistical Analysis

Paired t-test was done to evaluate the difference of tooth sizes between the right and left side. All the descriptive statistics were divided by gender because there are well known gender differences and Student t-test was used to determine whether any statistical significance existed in the tooth size and arch parameters between male and female samples. Comparisons of tooth size between the previous data[6] was also investigated by use of the Student t-test with estimated population standard error of the difference and pooled variance estimates.

RESULTS

The intra- and inter-examiner reliability coefficients were 0.9979 and 0.9963, respectively. In terms of root mean squares, the random errors of intra- and inter-examinesrs were lower than 0.083mm and 0.111mm, respectively.

Table 1 presents data on tooth sizes where the

Table 1. Result of paired t-test to evaluate the difference in tooth size between right and left sides (N = 296)

		Right			Left			Significance
		Mean	SD	SE	Mean	SD	SE	
Maxilla	Central Incisor	8.40	0.49	0.03	8.41	0.50	0.03	
	Lateral Incisor	6.92	0.51	0.03	6.88	0.52	0.03	**
	Canine	7.91	0.45	0.03	7.88	0.45	0.03	*
	1st Premolar	7.30	0.40	0.02	7.34	0.39	0.02	**
	2nd Premolar	6.80	0.42	0.02	6.79	0.40	0.02	
	1st Molar	10.45	0.64	0.04	10.44	0.55	0.03	
	2nd Molar	9.68	0.65	0.04	9.66	0.62	0.04	
Mandible	Central Incisor	5.23	0.34	0.02	5.29	0.52	0.03	*
	Lateral Incisor	5.86	0.37	0.02	5.89	0.37	0.02	
	Canine	6.82	0.40	0.02	6.86	0.41	0.02	***
	1st Premolar	7.23	0.41	0.02	7.21	0.41	0.02	
	2nd Premolar	7.03	0.44	0.03	7.02	0.43	0.03	
	1st Molar	10.96	0.60	0.04	10.94	0.57	0.03	
	2nd Molar	10.44	0.71	0.04	10.45	0.69	0.04	

Significant difference between right and left side $*P < 0.05$; $**P < 0.01$; $***P < 0.001$
SD: Standard deviation; SE: Standard error of mean

Table 2. Result of independent t-test to evaluate the difference in tooth size between males and females

		Male (N=179)			Female (N=117)			Significance
		Mean	SD	SE	Mean	SD	SE	
Maxilla	Central Incisor	8.55	0.45	0.03	8.19	0.44	0.04	***
	Lateral Incisor	7.00	0.51	0.04	6.74	0.46	0.04	***
	Canine	8.01	0.43	0.03	7.72	0.40	0.04	***
	1st Premolar	7.38	0.39	0.03	7.22	0.35	0.03	***
	2nd Premolar	6.86	0.38	0.03	6.70	0.40	0.04	***
	1st Molar	10.58	0.55	0.04	10.24	0.52	0.05	***
	2nd Molar	9.79	0.63	0.05	9.45	0.72	0.07	***
Mandible	Central Incisor	5.32	0.37	0.03	5.17	0.41	0.04	***
	Lateral Incisor	5.94	0.36	0.03	5.78	0.33	0.03	***
	Canine	6.98	0.37	0.03	6.62	0.32	0.03	***
	1st Premolar	7.30	0.39	0.03	7.10	0.37	0.03	***
	2nd Premolar	7.11	0.40	0.03	6.89	0.42	0.04	***
	1st Molar	11.11	0.56	0.04	10.71	0.48	0.04	***
	2nd Molar	10.62	0.66	0.05	10.17	0.64	0.06	***

Significant difference between male and female $***P < 0.001$
SD: Standard deviation; SE: Standard error of mean

difference between right and left sides are compared. Some teeth (e.g. lateral incisor, canine, and 1st premolar in the maxilla; central incisor and canine in the mandible) showed tooth size asymmetry between right and left sides. However, since the mean difference was a very small value, below 0.06mm at best, there was a natural doubt of this finding for the clinical implication.

However, the difference between males and females was clearly evident. Table 2 presents descriptive data on tooth size for both genders. The mean difference

Table 3. Result of independent t-test to evaluate the arch parameters between males and females

		Male (N=179)			Female (N=117)			Significance
		Mean	SD	SE	Mean	SD	SE	
Maxillary Arch Width	3-3	37.08	1.84	0.14	35.58	1.68	0.16	***
	4-4	45.57	2.23	0.17	43.91	1.97	0.18	***
	5-5	51.65	2.33	0.17	49.53	2.29	0.21	***
	6-6	56.80	2.62	0.20	54.46	2.57	0.24	***
	7-7	62.88	2.92	0.22	59.97	2.66	0.25	***
Mandibular Arch Width	3-3	28.15	1.82	0.14	27.20	1.64	0.15	***
	4-4	36.52	2.16	0.16	35.54	2.01	0.19	***
	5-5	42.65	2.48	0.19	41.20	2.39	0.22	***
	6-6	48.28	2.45	0.18	46.17	2.43	0.22	***
	7-7	54.28	2.97	0.22	51.81	2.51	0.23	***
Arch Width Ratio	3-3	75.94	3.45	0.26	76.40	3.69	0.34	
	4-4	80.17	3.17	0.24	80.90	3.08	0.29	
	5-5	82.58	3.13	0.23	83.11	2.79	0.26	
	6-6	85.02	2.55	0.19	84.68	2.76	0.26	
	7-7	86.34	2.75	0.21	86.36	2.57	0.24	
Maxillary Arch Length		38.49	3.36	0.25	37.18	3.06	0.28	**
Mandibular Arch Length		33.79	3.73	0.28	32.51	3.23	0.30	***
Bolton Index	3-3	77.45	2.47	0.18	77.62	2.62	0.24	
	6-6	90.47	1.86	0.14	90.32	2.00	0.18	

Significant difference between male and female $^{**}P < 0.01$; $^{***}P < 0.001$
SD: Standard deviation; SE: Standard error of mean

was a minimum of 0.15mm in the lower central incisor and a maximum of 0.44mm in the lower 2nd molar.

Table 3 presents the arch parameters and Bolton indices. Although all the linear measurements, which included arch width, basal arch width, and arch length, showed larger values in males than females, the concerned ratios and Bolton indices were identical.

DISCUSSION

With advancements in digital technology, a virtual computerized model is now being introduced for clinicians. However, measurement with digital calipers on plaster models are reported to have the highest accuracy and reproducibility than the computerized method.[7] Disadvantages of measurement based on a three-dimensional scanner are the increased time and limited practicability imposed on the practitioner, and the extensive hardware and software involved. Therefore, in a clinical setting, the instrument which is used in this study is not only useful but also more practical with a suitable reliability.

There has been a lot of research on the normative data of tooth size in Koreans. However, some reported the data with the genders pooled and without controlling for far outliers,[8] with a relatively small sample size,[9-12] The characteristic aspect of this study is that the largest size of normal samples was recruited among the references ever researched. The large sample size was designed in an early phase of the study to increase statistical power, which reduces Type II error, beta. As expressed in the 3rd column of the data tables, all standard error terms (SE) were very small when compared to the mean values. Due to the following reason, the term SE has been presented along with the standard deviation (SD): The SE, which is the square root by the sample size of SD, shows how close the

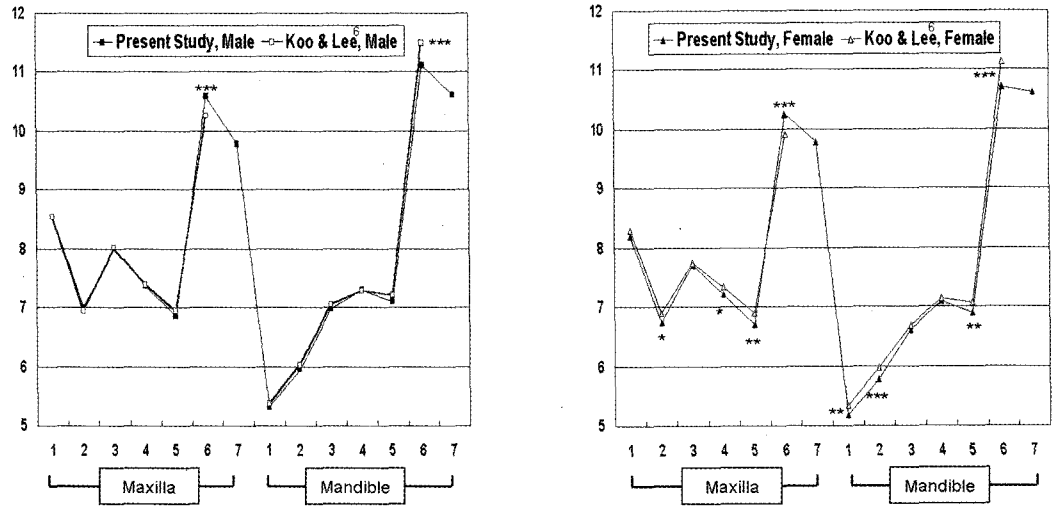

Fig 1. Comparison of tooth size measurements between the present study and previous data.[6] Significant difference between the present study and previous data are denoted as $*P < 0.05$, $**P < 0.01$, and $***P < 0.001$.

will be to the true (population) mean, whereas SD reflects how close individual scores cluster around their mean.[13] With a large sample size, it is expected that our data closely resembles the original (true population) distribution.

Additionally, reproducibility and accuracy of measurements is another important feature in designing a clinical experiment. In the year 1999, Sim and colleagues[14] investigated the magnitude of the tooth size measuring error in the crowded dentition. They found some difference according to the tooth and investigator with a varying degree and direction. They insisted that the possibility of tooth size measurement error should be taken into consideration when diagnosing an orthodontic case.[14] Fleiss[15] stated that no matter how reliable a measure has been found to be in the past, reliability should be assessed again prior to a new study. There is no guarantee, after all, that reliability will continue to be high for a new group of examiners obtaining measurements on a new sample of a study.[15] As a reliability assessments, Intraclass Correlation Coefficient (ICC) was used to test intra-and inter-examiner reliability, since the Pearson Product Moment Correlation Coefficient is known to be an inappropriate and liberal measure of reliability that usually overestimates the true reliability.[16] The intra- and inter-examiner reliability attained was over 0.99, which meant that our measurement could be interpreted with an excellent reliability.

It would not be insane to state that our society developed socio-economically during the past several decades. There has been an increase in body stature and other physical figures with a nutritional overflow. Because tooth size can be affected by nutrition,[1,17] to investigate secular change, our data were compared with a previous study, more than 20 years ago, by Koo and Kim,[6] which had the most similar set-up to our study. In the year 1981, they collected a relatively large sample, total n = 180, and handled the data very meticulously. After the inferential statistics with an estimated population standard error of the difference and pooled variance estimates, we found significant differences between our data and their data. However, we could not describe a uniform trend toward an increase or decrease (Fig 1). Between the clear statistical significances and uncertain secular trends, the explanation had to be confusing. And how can we interpret these findings? The age of subjects was similar and there were no outliers in those data. Two explana-

tions could be possible. First, in fact, if there were truly large differences, there may be no need for statistical tests. Because in those studies recruited large sample and the statistical test might have detected even very small difference as a statistically significant one. It is because of its highly increased sensitivity on account of a large sample size. Here, we would like to quote the statement of Bakan, "large sample size almost inevitably guarantees a significant result."[16] Second, according to Norman and Streiner,[13] statistical significance says nothing about the actual magnitude or the importance of the difference. They insisted that the statistical significance is a necessary precondition for a consideration of clinical importance.[13] In our study, the mean difference showed only a small value in proportion when compared with the original mean data, an average of 0.07mm and at best 0.43mm (female, lower 1st molar). Therefore, it would be safe not to report clinical or substantive significance between our data and the one from 20 years ago. And this again prudently suggested that an environmental factor has sparse influence on the tooth size.

Some tooth sizes showed asymmetry between the right and left side with statistical significance (Table 1), however, assuming the same dimension would be recommended because the mean difference was very small, lower than 0.04mm, which was lower than the random error and this differences meant nothing if any. This finding corresponded with the study of Garn and others,[17] in which they reported the symmetric property of human tooth size.

It was very interesting to find that the ratio variables showed no difference between genders. Although all the linear measurements, which in cluded tooth size, arch width, basal arch width, and arch length, reconfirmed the absolute statistical significance, males showed larger values than females, the concerned ratios and Bolton indices were identical. In addition, there was no difference between our data and data those from different ethnic samples.[4,5,18,19]

Traditionally, research concerned with tooth size and arch parameters were performed in relation to the malocclusion, especially as a source factor of crowding. However, on the other hand, some attention to the cases of crowding has been endowed in different directions: dental arch dimensions[20] or morphology of tooth,[21] for example. A long-lasting theme in orthodontics was to determine whether the variation in tooth size arose from the differences between normal data and malocclusion data or whether this variation is related to the original distributions. I Individual variation is not always variation from what we call "normal"; it may be simply a variation of "normal range" for which we had no ready explanation. A more explanatory methodology to this theme should be introduced in this respect.

CONCLUSION

In this report, the normative data for tooth size and arch parameters in Koreans were revisited with a large sample size as well as reliability measurements. Well-known differences between males and females, and homogeneity of arch width ratio as well as Bolton indices were reconfirmed. Although socio-economic status and physical parameters of Koreans have developed, tooth size and arch parameters were substantively not different from the report published in 1981.

REFERENCES

1. Lindsten R, Ogaard B, Larsson E. Dental arch space and permanent tooth size in the mixed dentition of a skeletal sample from the 14th to the 19th centuries and 3 contemporary samples. Am J Orthod Dentofacial Orthop 2002;122:48-58.
2. Lindsten R, Ogaard B, Larsson E. Transversal dental arch dimensions in 9-year-old children born in the 1960s and the 1980s. Am J Orthod Dentofacial Orthop 2001;120:576-84.
3. Kim JY, Lee SJ, Kim TW, Nahm DS, Chang YI. Classification of the skeletal variation in normal occlusion. Angle Orthod 2005;75:303-11. in press
4. Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod 1958;28:113-30.
5. Bolton WA. The clinical application of tooth-size analysis. Am J Orthod 1962;48:504-29.
6. Koo JH, Lee KS. Correlations between mesiodistal crown diameters of permanent teeth. Korean J Orthod 1981;11:143-50.
7. Zilberman O, Huggare JA, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. Angle Orthod 1003;73:301-6.

8. ParkYC. A morphologic study on straight wire bracket for Korean. Korean J Orthod 1991;21:481-94.
9. Ahn BK. A statistical study on the effect of tooth size and dental arch size upon the crowding. Korean J Orthod 1990;20:217-26.
10. Yang JW, Lee DJ. A study of bracket base (in-and-out) in Korean. Korean J Orthod 1990;20:355-61.
11. Lee JH, Lee DJ. A study on the relationship between tooth size and arch dimension in dental crowding. Korean J Orthod 1988;18:217-26.
12. Choi YJ, Park YC. A statistical study of dental crowding and its relationship to tooth size, and arch dimension and shape. Korean J Orthod 1984;14:263-72.
13. Norman GR, Streiner DL. Biostatistics: the bare essentials, Mosby St. Louis, 1996. pp. 40-8.
14. Sim EJ, Hwang HS, Moon JD. A study on the error of tooth size measurements. Korean J Orthod 1999;29:491-501.
15. Fleiss JL, The design and analysis of clinical experiments, John Wiley & Sons, New York, 1985 pp. 8.
16. Brunette DM. Critical thinking: Understanding and evaluating dental research. Chicago, IL; Quintessence Publishing Co, Inc 1996.pp 99-112.
17. Garn SM, Lewis AB, Kerewsky RS. The magnitude and implications of the relationship between tooth size and body size. Arch Oral Biol 1968;13:129-31.
18. Bernabe E. Major PW, Flores-Mir C. Tooth-width ratio discrepancies in a sample of Peruvian adolescents. Am J Orthod Dentofacial Orthop 2004;125:361-5.
19. Santoro M, Ayoub ME, Pardi VA, Cangialosi TJ. Mesiodistal dimensions and tooth size discrepancy of the permanent dentition of Dominican Americans. Angle Orthod 2000;70:303-7.
20. Howes RP, McNamara JA, O'Connor KA. An examination of dental crowding and its relationship to tooth size and arch dimension. Am J Orthod 1983;83:363-73.
21. Rhee SH, Nahm DS. Triangular-shaped incisor crowns and crowding. Am J Orthod Dentofacial Orthop 2000;118:624-8.

국문초록

한국인 정상교합자의 치아크기와 치열궁 계측치에 관한 연구

이신재[a], 문성철[b], 김태우[c], 남동석[d], 장영일[d]

본 연구에서는 한국인 정상교합자의 치아 크기와 치열궁 척도를 재평가하고자 하였다. 본 연구를 위하여 296명(남자 179명, 여자 117명)의 정상교합자 모형을 분석하였는데, 이 정상교합자 표본은 1999년부터 2002년까지 시행된 대규모의 구강 검진 사업에 대상이 되었던 15,836명의 성인 중에서 선발되었다. 0.01mm 정밀성을 보이는 슬라이딩 디지털 캘리퍼스를 이용하여 치아의 근원심 폭경과 치열궁 폭경, 치열궁 기저부 폭경 및 치열궁 장경을 측정하였으며, 구치부 폭경 비율과 Bolton의 지수를 도출하였다. 계측의 신뢰성 증진을 위한 방안들을 면밀히 고려하였으며, 측정시의 실험자내 및 실험자간의 신뢰성 지수를 산출하였다. 그 결과 자료의 신뢰성은 매우 우수하였으며, 측정된 자료에서는 명백한 성차가 다시금 확인되었다. 20년전의 자료와 비교한 결과 의미있는 차이는 발견되지 않았다. 각종의 선형 계측치의 경우 명백한 성차 및 인종간의 차이가 인정되지만 각종 비율 척도의 경우 성별 및 인종에 상관없이 같은 값을 보였다. 본 연구의 결과물은 임상적으로 부정교합 환자에게 적용 가능할 것으로 생각되었다.

주요 단어 : 치아 크기, 치열궁 척도, 정상교합 표본

서울대학교 치과대학 교정학교실
[a] 조교수, [b] 초빙교수, [c] 부교수, [d] 교수
교신저자: **장영일**
서울시 종로구 연건동 28
서울대학교 치과대학 교정학교실 / 02-2072-2600
drchang@plaza.snu.ac.kr
원고접수일 2004년 9월 16일; 원고최종수정일 2004년 10월 20일; 원고채택일 2004년 11월 6일