

The relationship between the incisor position and lingual surface morphology in normal occlusion

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Abstract This study aimed to investigate the relationship between the morphological characteristics of maxillary incisors and the anterior occlusion. The study materials comprised dental casts and lateral cephalograms of 26 modern Mongolian females with Angle Class I normal occlusion (mean age, 21 years 5 months). Computed tomography (CT) images of the dental casts were taken with an X-ray micro-CT system (SMX-100CT, Shimadzu, Kyoto Japan). The thickness of the marginal ridges and incisal edges, and the overjet and overbite, was measured on the three-dimensional images of the dental casts. On the lateral cephalogram, maxillary incisor to sella–nasion plane angle (U1 to SN angle), maxillary incisor to nasion-point A plane distance (U1 to NA distance), mandibular incisor to nasion-point B plane distance (L1 to NB distance), incisor mandibular plane angle, and interincisal angle were measured by tracing the left incisors of the maxilla and mandible. Spearman’s single rank correlation coefficients were used to investigate any correlation between measurement items for each maxillary incisor. The thickness of the marginal ridges and incisal edges was positively correlated with the overbite. The thickness of the incisal edges was positively correlated with the irregularity

index of the maxilla. There were significant negative correlations between overbite and U1 to SN angle, U1 to NA distance, and L1 to NB distance. Significant positive correlations were noted between the overbite and the overjet. In conclusion, there was no strong relationship between the morphological characteristics of maxillary incisors and the anterior occlusion.

Keywords Maxillary incisor · Marginal ridge · Micro-CT · Anterior occlusion · Mongolian

Introduction

A high frequency of shovel-shaped incisors is one of the features of the Mongoloid dental complex, which can be subdivided into two patterns: Sundadonty and Sinodonty [1]. Sinodonts are typical of North-East Asia (Northern China, Mongolia, and Southern Siberia) and are hypothesized to have evolved from the Sundadonts. Sinodonts have a significantly higher frequency of incisor shoveling. Shovel-shaped incisors are common characteristics in North-East Asian populations. In the typical shovel-shaped incisor, the lingual marginal ridges enclose a fossa, giving the appearance of a “coal shovel” [2, 3]. The marginal ridges of shovel-shaped incisors may be especially prominent and enclose a deep fossa in the lingual surface. It is hypothesized that the thick marginal ridges of shovel-shaped incisors affect the anterior occlusion. The shape of the lingual surface of the maxillary incisors may affect their occlusion with the mandibular incisors. Variations in the anatomical features of the maxillary incisors may affect either the treatment or the retention phase of orthodontic clinical practice [4, 5]. The morphological variability of teeth is an important consideration in the attainment of an

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optimum dental occlusion. Correction of incisor inclination is a major concern in orthodontics; the diversity of adequate incisor inclination influences a variety of aspects, including esthetics, the patient's self-perception, function, stability, and phonetics [6].

To demonstrate considerations for treatment planning in orthodontic clinical practice, the purpose of this study was to investigate the relationship between the morphological characteristics of maxillary incisors and the anterior occlusion.

Materials and methods

The study materials comprised dental casts and lateral cephalograms of 26 modern Mongolian females with Angle Class I normal occlusion (mean age, 21 years 5 months). The study materials were obtained in 2006 and 2007 from college or university students who were born in Ulaanbaatar or its suburbs and belonged to the Khalkha-Mongol grouping [7]. The study was approved by the Committee on the Ethics of Human Experimentation and the Nippon Dental University School of Life Dentistry at Niigata (Approval No. IN-88). All participants signaled their agreement on a consent form.

On the study casts, the sum of the displacements from the anatomic contact point to the contact point between the lower canines was measured using a pair of sliding digital calipers (Mitutoyo Manufacturing Co. Ltd, Kawasaki, Japan) to an accuracy of 0.05 mm, and Little's index of irregularity [8] was calculated. Based on this index, subjects deemed to have normal occlusion (<3.5 mm) were selected for the study. The sample size was calculated based on a power analysis using G Power Software version 3.1.5 (E Erdfelder, Psychologisches Institut der Universität, Bonn Romestr., Germany) for a Spearman's single rank correlation coefficient at alpha error probability of 0.05 and a power of 80 % (effect size = 0.50). The power analysis showed that 26 samples were required, so it was decided to enroll 26 modern Mongolian female samples. Other inclusion criteria for the samples were: (1) overjet and overbite within the range of 1–4 mm; (2) Angle Class I molar relationship; (3) all incisors in contact with opposing teeth; (4) fully erupted permanent dentition excluding wisdom teeth; (5) no tooth agenesis or extractions; (6) no proximal attrition; (7) no interproximal restorations; (8) no occlusal developmental anomalies in the dental arches; (9) no anomalies of crown morphology; and (10) no orthodontic treatment in either the maxillary arch or the mandibular arch. An X-ray micro-computed tomography (CT) system (SMX-100CT, Shimadzu, Kyoto, Japan) was used to take CT images of the dental casts. Figure 1 shows the positioning of the study casts for the X-ray micro-CT

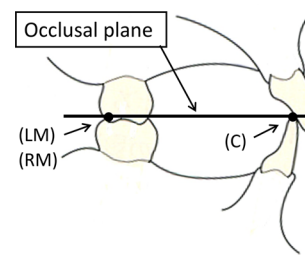
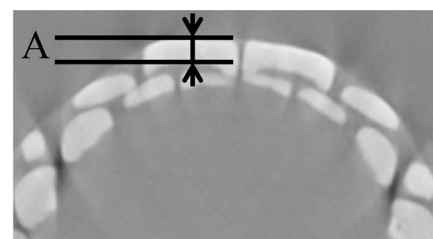
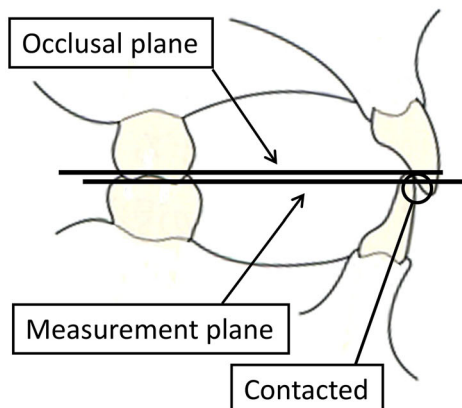


Fig. 1 Setting of the study cast for the X-ray micro-CT system. 1. On the study cast, the occlusal plane was set as a plane, including the incisal edge of the central incisor (C), tops of the distobuccal cusps of left and right first molars (LM and RM) on the mandible. 2. The casts were mounted on a rotary stage with the occlusal plane parallel to the stage of the X-ray micro-CT system

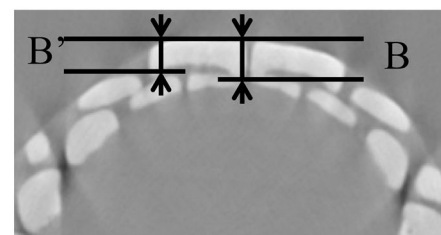
scan. The casts were scanned after mounting on a rotary stage with the occlusal plane parallel to the specimen stage. X-ray parameters were set at 87 kV and 64 μ A, and slice thickness was set at 0.12 mm. Three-dimensional (3D) images of each dental cast were reconstructed from the micro-CT data using the TRI/3D-Bon software (Ratoc System Engineering, Kyoto, Japan). An image of the lingual surface of each of the four maxillary incisors contacting its opposing tooth was selected and measured. From the 300 images taken by micro-CT, the image closest to the occlusal plane with contact of maxilla and mandibular central incisors was selected. The thickness of the marginal ridges and incisal edges was measured on the 3D image of the dental casts, as shown in Fig. 2. The measurement plane was set as the plane parallel to the occlusal plane, including the contact point of the maxillary and mandibular central incisors. Figure 3 shows the measurement of overjet and overbite on the 3D image of the dental casts. Overjet was set as the horizontal distance between the tangent line on the labial surface of the upper incisor and the tangent line on the labial surface of the lower incisor. Overbite was set as the perpendicular distance between the line including the incisal edge of the upper incisor and the line including the incisal edge of the lower incisor. These two lines were defined as parallel to the measurement plane. On the lateral cephalogram, maxillary incisor to sella–nasion plane angle (U1 to SN angle), maxillary incisor to nasion–point A plane distance (U1 to NA distance), mandibular incisor to nasion–point B plane distance (L1 to NB distance), incisor mandibular plane angle (IMPA), and interincisal angle were measured by tracing the left incisors of the maxilla and mandible.

Spearman's single rank correlation coefficients were used to investigate any correlation between measurement items for each maxillary incisor. The measurement errors were determined by duplicate measurements of all variables. Ten randomly selected dental casts from the study were measured and analyzed on two different occasions with an interval of at least 1 month. Measurement errors

Fig. 2 Measurements on the 3D images of study casts. 1. From the 300 images taken by micro-CT, the image closest to the occlusal plane with contact of maxilla and mandibular central incisors was selected. 2. The measurement plane was set as the plane in parallel with the occlusal plane, including the contact point of maxillary and mandibular central incisors

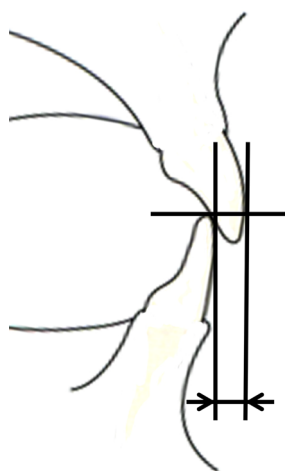


A: thickness of incisal edges

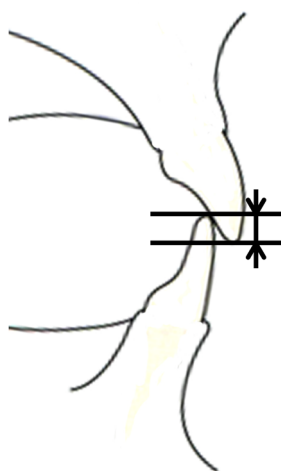


B: thickness of mesial marginal ridge
B': thickness of distal marginal ridge

Overjet



Overbite



Sagittal cross-sectional view of the anterior

Fig. 3 Overjet and overbite measurements on the 3D images of study casts

were analyzed by a procedure of double determination measurements, and the method was described by Dahlberg [9].

Results

There were no significant differences between the first and second measurements for all measurement items on the dental casts. The measurement errors calculated by the method of Dahlberg [9] ranged from 0.10 to 0.12 mm, and

were small compared with the mean values. Therefore, it was confirmed that the measurement errors of the method were relatively small and unlikely to bias the results.

Descriptive statistics for the tooth crown diameters, overjet, and overbite for the central and lateral incisors are shown in Table 1. The thickness of the marginal ridges ranged from 2.82 to 2.94 mm for central incisors and from 2.45 to 2.71 mm for lateral incisors. Descriptive statistics for the irregularity index and cephalometric dimensions for central incisors are shown in Table 2. The irregularity index of the mandible was 1.54 ± 0.62 , and that of maxilla was 1.25 ± 0.64 .

Spearman's single rank correlation coefficients for the four maxillary incisors (left and right central incisors, left and right lateral incisors) are shown in Tables 3 and 4. For maxillary central and lateral incisors, the thickness of the marginal ridges (mesial and distal) was positively correlated with the thickness of incisal edges ($p < 0.01$). The thickness of the marginal ridges and incisal edges was positively correlated with the overbite ($p < 0.01$). The thickness of the incisal edges was positively correlated with the irregularity index of the maxilla for the maxillary central (left: $p < 0.05$, right: $p < 0.01$) and lateral incisors ($p < 0.05$). The thickness of the marginal ridges, however, was significantly correlated with the irregularity index of the maxilla for the central incisors ($p < 0.05$) and the left lateral incisor ($p < 0.01$). There were significant negative correlations between overbite and U1 to SN angle ($p < 0.01$), U1 to NA distance ($p < 0.01$), and L1 to NB distance ($p < 0.05$) for each maxillary incisor. Significant positive correlations between overbite and the inter-incisal angle for the maxillary central (left: $p < 0.01$, right:

Table 1 Descriptive statistics for crown diameters, overjet, and overbite for the incisors (mm)

	Central incisors				Lateral incisors			
	Left		Right		Left		Right	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mesiodistal crown diameter	8.14	0.42	8.14	0.43	6.71	0.39	6.82	0.30
Thickness of mesial marginal ridge	2.91	0.61	2.87	0.57	2.45	0.64	2.71	0.77
Thickness of distal marginal ridge	2.94	0.66	2.82	0.65	2.56	0.76	2.67	0.84
Thickness of incisal edge	2.22	0.55	2.14	0.50	2.10	0.55	2.22	0.55
Overjet	2.55	0.63	2.56	0.60	2.22	0.46	2.28	0.51
Overbite	2.22	0.75	2.22	0.70	2.10	0.69	2.05	0.72

n = 26

Table 2 Descriptive statistics for the irregularity index and cephalometric dimensions for central incisor

	Mean	SD
Irregularity index, mandible	1.54	0.62
Irregularity index, maxilla	1.25	0.64
U1 to SN angle	104.25	4.32
U1 to NA distance	4.77	2.02
L1 to NB distance	4.75	1.62
IMPA	94.77	4.66
Interincisal angle	127.81	6.85

n = 26

p < 0.05) and lateral incisors (left: *p* < 0.01, right: *p* < 0.05) were observed. Significant positive correlations were also noted between overbite and overjet for the

central (*p* < 0.05) and lateral incisors (left: *p* < 0.05, right: *p* < 0.01).

Spearman’s single rank correlation coefficients for the irregularity index and cephalometric measurement items for the left central incisors in the maxilla and mandible are shown in Table 5. Some significant correlations were observed on the cephalometric measurement items; most notably, a positive correlation was observed between U1 to NA distance and L1 to NB distance (*p* < 0.01).

Discussion

For the central incisors, our result indicated that positive correlations were observed between the irregularity index of the maxilla and the labiolingual thickness of the tooth crown (marginal ridges and incisal edge) of the maxilla. On

Table 3 Spearman’s single rank correlation coefficients for the central incisors

	Thickness of mesial marginal ridge		Thickness of distal marginal ridge		Thickness of incisal edge		Overjet, central incisor		Overbite, central incisor	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Thickness of mesial marginal ridge	–	–								
Thickness of distal marginal ridge	0.864**	0.915**	–	–						
Thickness of incisal edge	0.829**	0.877**	0.868**	0.895**	–	–				
Overjet, central incisor	ns	ns	ns	ns	ns	ns	–	–		
Overbite, central incisor	0.469*	0.459*	0.538*	0.496*	0.390*	0.458**	0.560*	0.395*	–	–
Irregularity index, mandible	0.472*	ns	0.461*	ns	0.483*	0.427*	ns	ns	ns	ns
Irregularity index, maxilla	0.400*	0.444*	0.469*	0.393*	0.423*	0.500**	ns	ns	ns	ns
U1 to SN angle	ns	ns	ns	ns	ns	ns	ns	ns	–0.577**	–0.586**
U1 to NA distance	ns	ns	ns	ns	ns	ns	ns	ns	–0.578**	–0.675**
L1 to NB distance	ns	ns	ns	ns	ns	–0.428*	ns	ns	–0.402*	–0.467*
IMPA	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Interincisal angle	ns	ns	ns	ns	ns	ns	ns	ns	0.433*	0.504**

ns not significant

* *p* < 0.05, ** *p* < 0.01

Table 4 Spearman's single rank correlation coefficients for the lateral incisors

	Thickness of mesial marginal ridge		Thickness of distal marginal ridge		Thickness of incisal edge		Overjet, laterl incisor		Overbite, laterl incisor	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Thickness of mesial marginal ridge	–	–								
Thickness of distal marginal ridge	0.880**	0.925**	–	–						
Thickness of incisal edge	0.880**	0.928**	0.924**	0.938**	–	–				
Overjet, lateral incisor	ns	0.392*	ns	0.421*	ns	ns	–	–		
Overbite, lateral incisor	0.486*	0.466*	0.465*	0.446*	0.496*	0.444*	0.449*	0.620**	–	–
Irregularity index, mandible	ns	ns	ns	ns	ns	ns	–0.429*	ns	ns	ns
Irregularity index, maxilla	ns	ns	0.562**	ns	0.441*	0.433*	ns	ns	ns	ns
U1 to SN angle	ns	ns	ns	ns	ns	ns	ns	–0.433*	–0.499**	–0.586**
U1 to NA distance	ns	ns	ns	ns	ns	ns	ns	–0.493*	–0.676**	–0.765**
L1 to NB distance	–0.392*	–0.526**	–0.426*	–0.487*	–0.447*	–0.482*	ns	ns	–0.394*	–0.464*
IMPA	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Interincisal angle	ns	ns	ns	ns	ns	ns	ns	ns	0.490*	0.607**

ns not significant

* $p < 0.05$, ** $p < 0.01$

Table 5 Spearman's single rank correlation coefficients for the irregularity index and cephalometric dimensions of the central incisor

	Irregularity index, mandible	Irregularity index, maxilla	U1 to SN angle	U1 to NA distance	L1 to NB distance	IMPA	Interincisal angle
Irregularity index, mandible	–						
Irregularity index, maxilla	ns	–					
U1 to SN angle	ns	ns	–				
U1 to NA distance	ns	ns	0.462*	–			
L1 to NB distance	ns	ns	ns	0.606**	–		
IMPA	ns	ns	ns	ns	ns	–	
Interincisal angle	ns	ns	–0.483*	–0.676**	–0.726**	–0.546**	–

ns not significant

* $p < 0.05$, ** $p < 0.01$

the other hand, not so strong positive correlations were observed for the lateral incisors. Shoveling of incisors with thick marginal ridges occurs more frequently in the maxilla than in the mandible, with lateral incisors affected more frequently than central incisors [2, 10]. Dahlberg [11] suggested that the last tooth to develop in each field tends to be the most variable in size and shape, applying Butler's field theory to the human dentition. The central incisors are "key" teeth in the maxillary incisors' field. Meanwhile, the lateral incisors are located at the distal end of the maxillary incisors' field. The shapes and sizes of lateral incisors were tended to be more variable compared with central incisors. Thus, a significant correlation between the irregularity

index of the maxilla and the thickness of the marginal ridge was found only on the distal side of the left lateral incisors. It may be considered that variability in the size of the teeth and jaw may be a predisposing factor [12]. The labiolingual thickness of tooth crowns (marginal ridges and incisal edge) was negatively correlated with L1 to NB distance for the lateral incisors, whereas there was a negative correlation between the thickness of the incisal edge and L1 to NB distance only for the central incisors. However, no significant correlations were observed between the thickness of the tooth crowns (marginal ridges and incisal edge) and IMPA for central and lateral incisors. The position of the mandibular incisors is affected by natural oral function,

facial harmony, and periodontal tissues, and arises from a complex combination of these factors [13]. Huang and Årtun [14] focused on the postretention malalignment of the maxillary and mandibular anterior teeth and reported no tendency of the mandibular incisors to rotate into the concavity of the maxillary central incisors in patients with prominent marginal ridges. Accordingly, they concluded that prominent ridges in the maxillary incisors may not be a risk factor for the development of mandibular incisor irregularity. In this study, there were some correlations between the irregularity index of mandible and the labiolingual crown thickness for the maxillary central incisor; however, these presences of correlation could not support that the labiolingual crown thickness of maxillary incisor is one of the factors affecting mandibular incisor position.

A large variation in skeletal relationships has been reported even in normal occlusion samples [15, 16]. Kim et al. reported that there was a wide range of normal variations not only in skeletal relationships, but also in dentoalveolar compensation within normal occlusion samples [17]. Changes in tooth position and inclination, whether related to skeletal factors, functional factors, or both, are thought to result from a mechanism of compensation [18, 19]. Natural oral function is related to correct positioning of the maxillary and mandibular incisors to achieve facial harmony, and involves the dentalveolar process, and the bone tissues that support them. Hence, the dentition can be analyzed as a balance between the dentoalveolar process and the surrounding musculature [6, 20, 21]. In this study, for the maxillary central and lateral incisors, the thickness of the marginal ridges and incisal edges was positively correlated with the overbite. There were significant negative correlations between the overbite and all cephalometric measurement items except IMPA for each maxillary incisor. For the cephalometric measurement items, a positive correlation was found between U1 to NA distance and L1 to NB distance. These results may indicate the mechanism by which the overbite increases. Eberhart [22] stated that an average of 0.1–0.2-mm change in overbite occurs for every degree of change in the incisal angle in the long axis to the occlusal plane. Bibby [23] suggested that a compensation mechanism exists that allows maxillary and mandibular incisors to harmonize in a normal relationship regardless of skeletal class.

The results of this study could not support that the labiolingual crown thickness of maxillary incisor is one of the factors affecting mandibular incisor position. The position of the mandibular incisors is affected by natural oral function, facial harmony, and periodontal tissues, and arises from a complex combination of these factors. In conclusion, there was no strong relationship between the morphological characteristics of maxillary incisors and the anterior occlusion.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical approval Approval for the study was granted by the Committee on the Ethics of Human Experimentation, The Nippon Dental University School of Life Dentistry at Niigata (Approval No. IN-88). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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