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Original research

Differences between the chewing and non-chewing sides of the mandibular first molars and condyles in the closing phase during chewing in normal subjects

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ABSTRACT

Objective: This study aimed to assess differences between the closing paths of the chewing and non-chewing sides of mandibular first molars and condyles during natural mastication, using standardized model food in healthy subjects.
Design: Thirty-two healthy young adults (age: 19–25 years; 22 men, 10 women) with normal occlusion and function chewed on standardized gummy jelly. Using an optoelectric jaw-tracking system with six degrees of freedom, we recorded the path of the mandibular first molars and condyles on both sides for 10 strokes during unilateral chewing. Variables were compared between the chewing side and the non-chewing side of first molars and condyles on frontal, sagittal, and horizontal views during the early-, middle- and late-closing phases.
Results: On superior/inferior displacements, the chewing side first molar and condyle were positioned superior to those on the non-chewing side during the early- and middle-closing phases. Conversely, the first molar and condyle on the non-chewing side were positioned significantly superior to those on the chewing side during the late-closing phase. On anterior/posterior displacements, the chewing side mandibular first molar and condyle were positioned significantly posterior to those on the non-chewing side throughout all closing phases.
Conclusion: Our results showed the differences between the mandibular first molars and condyles on both sides with respect to masticatory path during natural chewing of a model food. These differences can be useful for informing initial diagnostic tests for impaired masticatory function in the clinical environment.

1. Introduction

Mastication results from the interaction of an intrinsic, rhythmical neural pattern and sensory feedback generated by the interaction of the masticatory system with food (Lund, 1991; Lund and Kolta, 2006). The generation of a smooth masticatory movement of the mandible is important for health, to break down food particles into small pieces (Wang & Mehta, 2013; Wilding & Lewin, 1994; van der Bilt, 2011). During this processing of food, muscle activity is used to exert force and to control the direction of mandibular closure precisely (Pr & schel & Raum, 2001; Slagter, Bosman, van der Glas, & van der Bilt, 1993). The masticatory path during mandibular closure has been differentiated into two phases based on the activities of the mandibular closing muscles (Lund, 1991). The fast-closing phase, which has the lowest level of closing muscle electromyography activity, occurs directly after the start of jaw closure until the teeth come into contact with the food bolus. The resistance of the food slows down the lower jaw, and the jaw closure muscles become more active to overcome the resistance of the food; this is called the slow-closing phase. At the final mandibular closure, the so-called occlusal phase, there is approximately isometric contraction of the closure muscles, and numerous studies have shown that the pattern of the masticatory path is influenced by the individual pattern of occlusal guidance (Belser & Hannam, 1985; Hannam, De Cou, Scott, & Wood, 1977; Rilo, Fernández-Formoso, Mora, Cadarso-Suárez, & Santana, 2009; Witter, Woda, Bronkhorst, & Creugers, 2013).

It is assumed that the first molar region plays an important role in masticatory function, because the number of occlusal contacts as well as the magnitude of bite forces acting on them are greater for first molar teeth than for pre-molar or anterior teeth (Hidaka, Iwasaki, Saito, & Morimoto, 1999; Hattori et al., 2009). Previous studies have attempted to clarify the masticatory mechanism on the first molar and

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condylar points. In natural chewing, it has been reported that the path of the lower central incisor point differs from that of the mandibular first molar at final closure (Dejak, Młotkowski, & Romanowicz, 2003; Gibbs & Lundeen, 1982; Gibbs, Lundeen, Mahan, & Fujimoto, 1981; Hayasaki et al., 2003; Miyawaki et al., 2001). The chewing side first molar moves slightly anteriorly (mean: 0.3 mm; range, 0–0.54 mm) in the final closing path (Gibbs et al., 1981). Furthermore, a previous study has reported that the condyle underwent a large upward movement on the non-chewing side during controlled submaximal clenching using unilateral occlusal stops (Okano, Baba, & Ohyama, 2005). In addition, it has been revealed that the condyle–fossa distance on the non-chewing side was smaller than that for the opening phase of a chewing cycle, as determined by measuring the variation of the minimum condyle–fossa distance (Palla, Gallo, & G & ssi, 2003). These reports suggested that the mandibular jaw tilts due to a slight elevation of the non-chewing side mandibular arch during the final stage of mandibular closure. However, the differences between the functional and non-functional sides in the paths of the mandibular first molar and condyle throughout mandibular closure during natural chewing are not known.

The aim of this study was to assess the differences between the closing paths of the chewing and non-chewing side mandibular first molars and condyles during natural mastication using standardized model food. For this purpose, we examined the masticatory paths, by directly observing the mandibular first molars and condyles on both sides in the frontal, sagittal, and horizontal view during unilateral chewing with normal occlusion.

2. Materials and methods

2.1. Subjects

The study protocol was reviewed and approved by the Ethics Committee at our hospital (#25-116). The study was conducted in full accordance with ethical principles, including those of the World Medical Association Declaration of Helsinki. It is advisable to give ethical approval upfront. All subjects provided their written, informed consent after receiving an explanation of the study's goals and structure.

Thirty-two healthy young adults (mean age: 22.7 years; range: 19–25 years; 22 men, 10 women) with normal occlusion and function were selected for this study. We examined the participants' clinical information and clinical signs and symptoms of temporomandibular disorders (TMDs), (i.e., temporomandibular joint [TMJ] sounds, tiredness/stiffness, pain, limitations in opening the mouth (< 5.0 mm), and TMJ locking or impaired opening) by clinical examination and questionnaires based on the Research Diagnostic Criteria for TMD Axis I (Dworkin & LeResche, 1992). The study inclusion criteria included: (1) a complete Angle Class I canine and molar relationship, (2) normal overjet and overbite, (3) fully emerged permanent dentition (excluding third molars), (4) no signs or symptoms of TMD, (5) little crowding and rigid intercuspation, and (6) no current or recent dental or orthodontic treatment.

2.2. Test foodstuffs

Standardized 5-g gummy jelly (Meiji Seika Kaisha Confectionery R & D Labs, Saitama, Japan) (Kitashima, Tomonari, Kuninori, Uehara, & Miyawaki, 2015; Miyawaki et al., 2005; Tomonari et al., 2014b) was specially prepared for the present study. The shape of the gummy jelly was similar to that of a truncated cone (5-g gummy jelly: height, 11 mm; top diameter, 12 mm; base diameter, 22 mm). The truncated cone shape was chosen because of its high stability, which ensured that a consistent height could be maintained when positioning the food on the occlusal surface and during chewing. Other relevant characteristics of the food used in the present study were as follows:

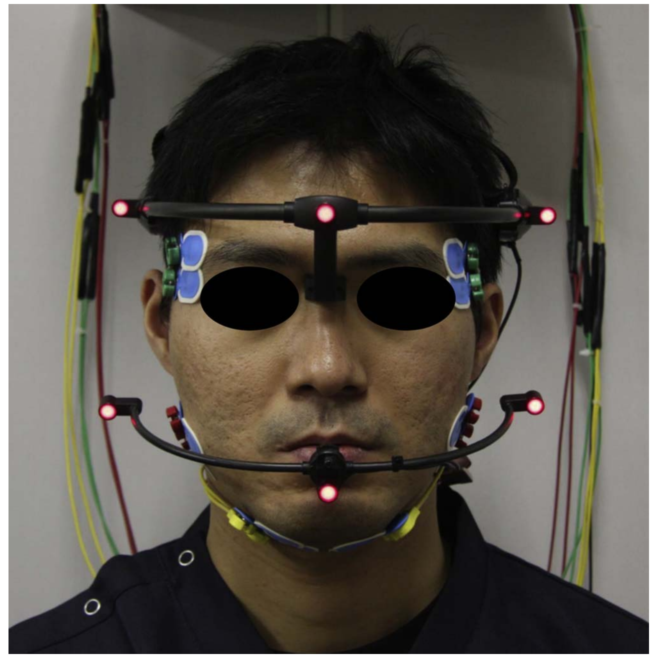

Fig 1. Subject is wearing a head frame and a face bow fixed to the end of a dental clutch at the CO position.

color (yellow), taste (orange), hardness (30.5 kg), cohesiveness (0.89 TU), and strain (21.9 TU). The mechanical characteristics of the test gummy jelly were measured using a texturometer (GTX-2, Zenken Company Ltd., Tokyo, Japan), as previously described (Miyawaki, Ohkochi, Kawakami, & Sugimura, 2001b).

2.3. System for recording masticatory path

2.3.1. Jaw movement

For all participants, we examined the lower central incisor, mandibular first molar, and TMJ paths on both sides, during open − close jaw movement using an optoelectric jaw-tracking system with six degrees of freedom (Kitashima et al., 2015; Miyawaki, Tanimoto, Kawakami, Sugimura, & Takano-Yamamoto, 2001a; Tomonari, Ikemori, Kubota, Uehara, & Miyawaki, 2014a). The system consisted of a head frame, a face bow, a pointer, light-emitting diodes (LEDs), CCD cameras, an amplifier, and a personal computer (Gnathohexagraph system Ver. 1.31; OnoSocki Ltd, Kanagawa, Japan) (Fig. 1). The sampling frequency was 89.3 Hz. The accuracy of the optical recording system was assessed using the method described by Tokiwa (Tokiwa 2001). They established 1530 three-dimensional reference points inside a 140 (X-axis) by 160 (Y-axis) by 50 mm (Z-axis) cuboid at 10-mm intervals using a full view of the XYZ stage-type calibrator. These reference points were located with LEDs and measured by the Gnathohexagraph system. Finally, the mean differences and standard deviation of the reference points and measurement points was calculated. The results of the accuracy tests for the equipment showed that the three-dimensional accuracy in terms of mean difference was 0.12 mm (standard deviation [SD] ± 0.06 mm). The head frame and face bow, each with three LEDs, were attached securely to the head and the dental clutch, which was bonded to the labial surface of the lower incisors. The clutch was bent to ensure that the movement of the mandible and lip was inhibited as little as possible. Using a pointer with two LEDs, the three-dimensional positions of the porion on both sides and the left infra-orbital point (Frankfort plane as the horizontal reference plane) were recorded by the jaw-tracking system. The lower central incisor point and the mandibular first molars' mesio-buccal cusps on the right and left sides were also recorded using this pointer. Subsequently, the bilateral condylar points were identified on the skin