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Research Article

Effect of Clenching via Mouth-guard and Influence of Mouth-guard Occlusal Support Area on Lateral Mandibular Impact of Skull Model

Yoshihiro Suzuki[1*], Kazunori Nakajima[1], Yoshiaki Kawano[1], Masayasu Nishino[1], Yoshiaki Matsuda[1], Tomotaka Takeda[1], Kenichi Fukuda[2]

[1]Division of Sports, Department of Oral Health and Clinical Science Dentistry, Tokyo Dental College, Tokyo, Japan; [2]Division of Special Needs Dentistry and Orofacial Pain, Department of Oral Health and Clinical Science Dentistry, Tokyo Dental College, Tokyo, Japan

ABSTRACT

Objective: Many studies have confirmed the benefits of wearing Mouth-Guards (MG) on the prevention or reduction of sport-related stomatognathic system trauma. However, custom made MG with high adaptability can be retained in a dentition even when the mouth is open; this situation thought to increase jaw fragility and the possibility of trauma. This study investigated the effects of the clenching with MG, and occlusal support area difference on mandibular distortions related to injury caused by direct lateral impact.

Materials and Method: A pendulum-type device was used to apply an impact on the lower-left region of the mandibular body of a skull model. MGs with different occlusal support areas were fabricated for various conditions. A pseudo-occlusal force of approximately 30 N was applied in the submental region for the model except for mouth open of control condition during impact. Evaluation criteria included the degree of mandibular distortion.

Results and Discussion: Large distortion was indicated during the impact when the mouth was open ($p<0.01$). In contrast, distortion was lowest when the mouth was clenched with fully supported MG ($p<0.01$); however, distortion increased when the occlusal support area of MG was reduced. Results indicated that clenching with appropriately designed MG is useful for the prevention and reduction of mandibular injuries.

Keywords: Mouth-guard; Bone fracture; Occlusal; Trauma

INTRODUCTION

Various experimental and clinical studies have reported the effects of Mouth-Guards (MG) on the prevention and reduction of trauma on the stomatognathic system [1-4]. Research shows that benefits are expected for head and neck injuries such as concussions, and mandibular injury is no exception [5-7]. Nevertheless, there are still reports of injury despite the MG application [1,8].

Impact or shock force is defined as a force applied to a target with a change in speed over a short duration of time. Generally speaking, the power is immense and the duration is very short. Additionally, momentum and total power are invariable before and after impact. Therefore, when impact power is applied to a human body, there are two entirely different results. If the energy is not great enough to cause damage to the body, it is consumed as heat energy by the viscosity of the joints or soft tissue. If the energy exceeds this limit, however, it becomes destructive, causing damage to the soft tissue, tooth dislocation and fracture, and bone fracture [5].

The mandible is especially susceptible to damage by external force depending on location, structure, and morphology; the site of mandibular fracture in response to impact reflects the vulnerable structure and mechanical weakness [9]. Mandibular fracture is a common occurrence in situations of high energy blunt force trauma [10,11]. Therefore, in order to prevent injury, the amount of kinetic energy transferred to the mandible must be reduced, and energy concentration must avoid.

Correspondence to: Yoshihiro Suzuki, Department of Oral Health and Clinical Science Dentistry, Tokyo Dental College, Chiyoda, Tokyo, Japan, Tel: +81-3-6380-9177; E-mail: fukamizuyoshihiro@tdc.ac.jp

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When the strength of impact force and difference of impact material is put aside, possible reasons for injuries even when MG is worn can be due to lack of evasive behavior at times of danger or the quality of occlusal relationship on the MG.

MG was effective for mandibular fracture against a direct blow to the mandibular under surface [5]. Nevertheless, a high incidence of trauma in the mandibular region thought to be greater in instances where the mouth is open. One of the conceivable reasons is due to a custom-made MG, which has excellent adaptability and retention, allowing the device to stay in place even without clenching.

The quality of the occlusal relation on MG may also influence mandibular injury [12]. Some papers reported that the proper occlusal relationship of MG significantly improved safety [3,13]. These raise the possibility that reduction or changes in occlusal support area due to incorrect occlusal adjustments, design, and selection of MG can influence the degree of mandibular trauma [1,5,14].

However, no study has clarified the effect of mandibular injury prevention with clenching via MG and the influence of occlusal support differences in response to directlateral impact.

The aim of the study was to investigate the effects of clenching with MG and occlusal support area on mandibular distortions related to trauma caused by lateral direct impact force using an artificial skull model.

MATERIALS AND METHODS

A skull model (ZA20; 3B Scientific International, Co. Ltd, Niigata, Japan) was used. The lower left body of the mandible was selected as a directly impacted region. Experimental conditions during impact included the following: a: Open mouth (OPEN); b: No MG with clenching (NOMG-CL); c: 7-7 MG with clenching (7-7 MG-CL); d: 3-3 MG with clenching (3-3 MG-CL); e: 7-4|4-7 MG with clenching (7-4|4-7 MG-CL); f: 7-4|MG with clenching (7-4| MG-CL); g: 7-4|4-7 MG with clenching (|4-7 MG-CL) (Figure 1).

Fabrication of the tested MG; pressurized moldings were carried out using thermoforming Suzuki Y material of ethylene-vinyl acetate (EVA) (Drufosoft 3 mm Clear, Dreve-Dentamid GMBH, Unna, Germany) and an air pressure machine and Drufomat SQ (Dreve-Dentamid GMBH)(3). Two sets of the MG were prepared (Figure 1)

The final adjustment on MG was made so that occlusal thickness was approximately 2 mm on the first molar and uniform occlusal contact at 7-7. After that, produced MG cut to each occlusal condition. For OPEN, a sponge was placed between the upper and lower first premolars for a 2 cm space.

A force of approximately 30 N was applied at the submental region with an acrylic plate using a manual muscle strength meter (Mobie, Sakai Medical Co., Ltd. Tokyo, Japan) to simulate occlusal force for clenching (Figure 2). Force was applied in a perpendicular direction to the occlusal plane.

Distortion was measured in 2 regions often involved in mandibular fractures (Figure 3): the mandibular body on the impact side (an area involved in direct fracture) and the mandibular condylar neck on the non-impact side (an area involved in the indirect fracture).

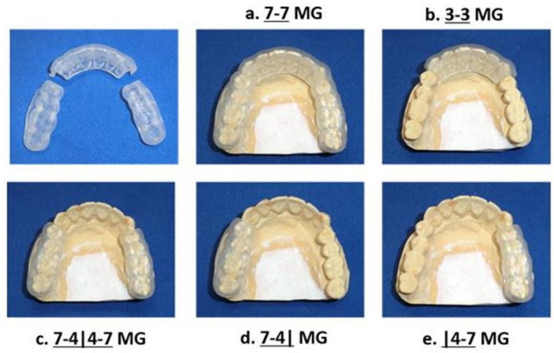

Figure 1: Mouth-guard prepared from EVA. Therefore, 7-7 MG cut to each condition: a. 7-7 MG; b. 3-3 MG; c. 7-4|4-7 MG; d. 7-4| MG; e. |4-7 MG.

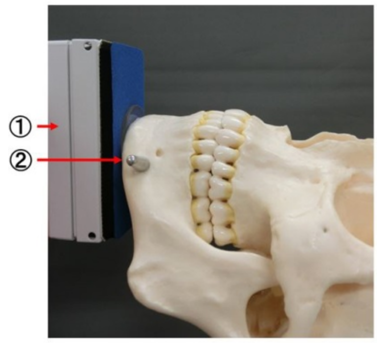

Figure 2: (1.) Manual muscle strength meter: a force of approximately 30 N was applied at the submental region; an acrylic plate was used to simulate occlusal force. The clenching force applied in a perpendicular direction to the occlusal plane; (2.) Impact point: a protrusion was set up on the impact site of the mandibular body.

A double-axis strain gauge (KFG 1-120-D 16-11 LIM 2 S, Kyowa Electric Industrial Co., Ltd.) was attached to each measurement point so that one axis was parallel to the main direction of the impact force and the other axis was in the vertical direction. As an impacting device, a pendulum-type similar to that used in Takeda et al. was used [13] (Figure 4). A 1 kg iron ingot was used as an impact object and released from a distance of 10 cm. Impact direction was regulated vertically on the sagittal plane on the skull model. The impact point was established at the center of the impact object by projection given to the impact point. Five measurements were made at each condition. Distortions were recorded and stored using a memory recorder analyzer (EDX-1500A, Kyowa Electric Industrial Co., Ltd.), and analyzed using designated analysis software (DAS-100A, Kyowa Electric Industrial Co., Ltd.). The values of the 2 axes in each measurement were added, and the mean and standard deviation were calculated. For statistical analysis, one-way ANOVA was used to compare OPEN, NOMG-CL, and 7-7 MG-CL. In addition it was used for the comparison among 5 experimental occlusal conditions (α=0.01). Turkey's multiple comparisons were performed using software (Excel Statistics 2015, Social Survey Information Co., Ltd. Tokyo, Japan) ($p<0.01$).

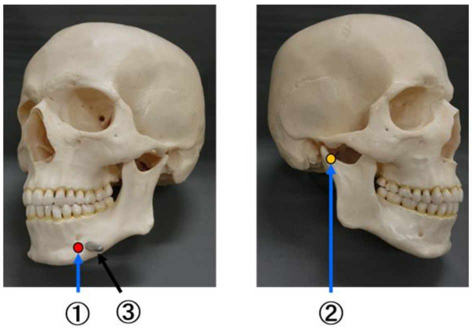

Figure 3: Sites where distortion was measured: (1.) mandibular body on the impact side (region involved in direct fracture); (2.) the mandibular condylar neck on the non-impact side (region involved in the indirect fracture); (3.) Impact point.

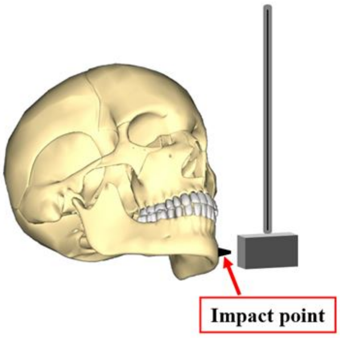

Figure 4: Impact point: Impact direction was regulated on the sagittal plate of the skull model. A 1 kg iron ingot was used as an impact object. The object was released from a distance of 10 cm. Impact force was applied to the lower left body of the mandible.

RESULTS

Effects of clenching and 7-7 MG (comparison between 3 conditions: OPEN, NOMG-CL, and 7-7 MG-CL)

One-way ANOVA revealed significant differences among the 3 different conditions at each point.

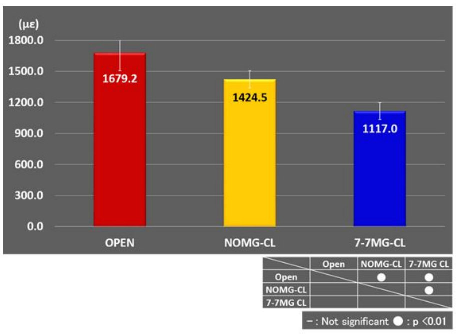

Figure 5: Distortion of the mandibular body on impact side: comparison among 3 conditions (OPEN, NOMG-CL, and 7-7 MG-CL).

1) The mandibular body on the impact side (Figure 5): Distortion values were decreased in the order of OPEN, NOMG-CL, and 7-7 MG-CL. Significant differences were found among all three conditions. The value for 7-7 MG-CL was 33% lower compared to OPEN.

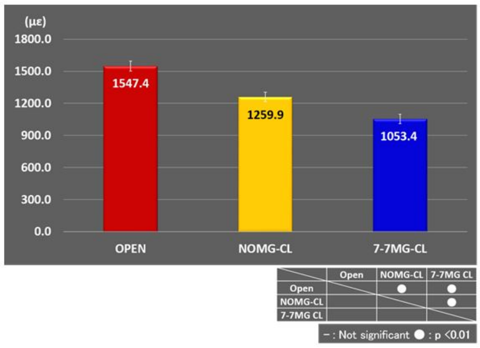

Figure 6: Distortion of the mandibular condylar neck on the non-impact side; comparison among 3 conditions (OPEN, NOMG-CL, and 7-7 MG-CL).

2) The mandibular condylar neck on the non-impact side (Figure 6): Distortion values decreased in the order of OPEN, NOMG-CL, and 7-7 MG-CL. Significant differences were found among all three conditions. The value for 7-7 MG-CL was 32% lower compared to OPEN.

Influences of MG occlusion

One-way ANOVA revealed significant differences among the 5 different conditions at each point.

1) The mandibular body on the impact side (Figure 7): On the impact side, values decreased in the order of 7-4| MG-CL, 7-4|4-7 MG-CL, 3-3 MG-CL, |4-7 MG-CL, and 7-7 MG-CL. The distortion value of 7-7 MG-CL was significantly lower than the others. The value of 7-4| MG-CL was also significantly greater than others.

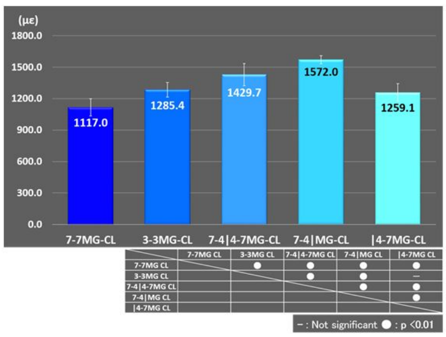

Figure 7: Distortion of the mandibular body on the impact side; comparison among 5 conditions.

2) The condylar neck on non-impact side (Figure 8): On the non-impact side, values decreased in the order of 3-3 MG-CL, 7-4|4-7 MG-CL, |4-7 MG-CL, 7-4| MG-CL, and 7-7 MG-CL. The distortion value of 7-7 MG-CL was significantly smaller than the others.

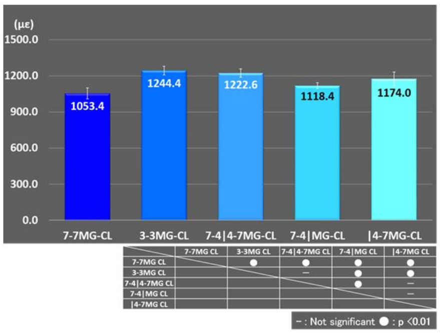

Figure 8: Distortion of the mandibular condylar neck on non-impact side; comparison among 5 conditions.

DISCUSSION

In general, intrinsic and extrinsic factors cause injuries. Dental related intrinsic factors include lack of understanding for the necessity to wear MG [14], and lack of evasive behavior [7,15] when in danger. Extrinsic factors include an insufficient thickness of MG [16,17] and a lack of occlusal adjustment of MG [12,13] among others.

On the influence of clenching with or without 7-7 MG (comparison among 3 conditions: OPEN, NOMG CL, 7-7 MG-CL). Mandibular distortion was greatest in the 2 regions during OPEN. The large distortion value for OPEN is likely due to the fact that the total energy of the impact was received by the mandible alone. Because, when the mouth is open, the mandible is only connected with the temporomandibular joints. However, in the clenched state, the mandible is unified with the maxilla, the mandibular body becomes rigid.

Smaller distortion value of NOMG-CL, when compared to OPEN, was consistent with what Tanaka et al. referred to as the impact reduction effect [18]. An impact reduction effect of clenching is the strengthening of the anti-gravitational muscles that stabilize the mandibular body. In the present study, the pseudo-clenching stabilized the mandible; and the force was propagated and dispersed to the maxilla resulting in lowered distortion.

The smaller distortion value of 7-7 MG-CL compared to NOMG-CL was due to the fact that clenching with the MG tensed up the entire mandible and the force was transmitted and dispersed to the maxilla. In addition, the shock-absorbing effect of MG most likely contributed to the lowest distortion value [1,3].

Direct fracture is trauma caused at the point of impact, and the occurrence is high in the mandibular body and the mandibular angle [9]. In this study, OPEN displayed the largest and 7-7 MG-CL displayed the lowest distortion on the impact site of the mandibular body. Distortion of 7-7 MG-CL was low because the energy of impact dispersed as a result of clenching with the MG. This result is consistent with a trauma study of anterior maxillary teeth and the alveolar part of the maxilla [19]. From these results, it was suggested that 7-7 MG placement and clenching is effective for the prevention or reduction of the direct fracture.

According to Uchiyama et al., there is a high frequency of indirect fracture on the condylar neck on the non-impact side [9]. In this study, distortion was the largest in OPEN and smallest in 7-7 MG-CL at the condylar neck. During OPEN, the mandibular joint is fixed only by the temporomandibular joint, and as reported by Korioth et al., stress concentrates at the mandibular condyle [20]; this is in agreement with our results in that OPEN demonstrated by the considerable distortion value. During OPEN, it was most likely that lateral rotation of the mandible occurred as a result of stress concentration on the non-impact side at the mandibular condylar neck. Furthermore, the result of NOMG-CL and 7-7 MG-CL is consistent with another study which mentioned that wearing the MG and clenching effectively reduced the amplitude and duration of acceleration of the head and TMJ during a blow to the jaw under surface [18]. In this current study, pseudo clenching may have prevented lateral rotation of the mandible which reduced the concentration of stress on the non-impact side of the mandibular condyle. As a result, decreased distortion on the non-impact side condylar neck observed in the clenching state regardless of whether MG was placed or not. The condylar neck is adjacent to the temporomandibular joint, and the impact force may affect the joint. Therefore, it is important to pay attention during play and to clench to decrease traumatic temporomandibular arthritis and ankyloses in athletes [21-23].

Judging from distortion values, 7-7 MG-CL demonstrated the highest benefits against mandibular trauma. From the studies, the correct occlusal relationship is necessary to enhance the safety of MG [12-13]. As Hasegawa reported, the effect of vibrational absorption is influenced by the form of MG, improper occlusal adjustment, and the design of MG can cause unexpected distortion of the mandible [24]. The decrease in the MG occlusal support area might increase an unsteadiness of the mandible and the force transmitted to the maxilla in this study. The proper occlusal support area in the MG could prevent mandibular trauma.

On the impact side, 7-4| MG-CL demonstrated the most considerable distortion compared to other MG-CL. The reason was that the mandible is fixed only at 7-4| by clenching with MG so that the impacted side of the mandibular body is in a similar state to OPEN; the impact energy could not be transmitted to the maxilla and dispersed which resulted in greater distortion. This result suggests that lateral trauma when occlusal support area only exists on the non-impact side is dangerous. This situation may occur in both boil and bite type and custom-made type MG when deep surface imprints of antagonistic teeth become a fulcrum [12]. This position, which often occurs position during fatigue or physically damaged conditions, maybe dangerous.

The findings of the present research suggest that it is important to clench to prevent and reduce trauma in the mandible. Tanaka et al. suggested that so long as athletes use a well-fitted proper MG, they do not have to clench their teeth continuously [18]. However, when they anticipate or receive a blow to the mandible, it seems to be important to clench to obtain the protective effects as an evasive behavior. Athletes, athletic trainers, instructors, sports doctors, and so on, should be aware that firmly clenching with proper MG at the time of receiving impact is effective for prevention of mandibular injury and concussion [5,7, and 15].

This study examined the effects of clenching with MG and the influence of the MG occlusal support area on mandibular distortion in response to direct lateral impact, using the skull model. We limited the scope of our investigation to only one fabrication system and impact point. However, our results strongly suggested the importance of clenching with MG and sufficient occlusal support area on the MG.

CONCLUSION

This study examined the effects of clenching with MG along with proper occlusal support area, on mandibular distortion against the direct lateral impact using a skull model. Within the limitations of this *in vitro* study, the followings can be concluded:

- Clenching was effective, and clenching with 7-7 MG was more effective for safety
- Decreases in the occlusal support area of the MG resulted in increased distortion

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Bemelmanns P, Pfeiffer P. Shock absorption capacities of mouth-guards in different types and thicknesses. Int J Sports Med. 2001; 22:149-153.
2. Handa J, Takeda T, Kurokawa K, Ozawa T, Nakajima K, Ishigami K. Influence of pre-laminated material on shock absorption ability in specially designed mouth-guard with hard insert and space. J Prosthodont Res. 2011;55:214-220.
3. Ozawa T, Takeda T, Ishigami K, Narimatsu K, Hasegawa K, Nakajima K, et al. Shock absorption ability of mouth-guard against forceful, traumatic mandibular closure. Dent Traumatol. 2014;30:204-210.
4. Takeda T, Ishigami K, Handa J, Naitoh K, Kurokawa K, Shibusawa M, et al. Does hard insertion and space improve shock absorption ability of mouth-guard? Dent Traumatol. 2006;22:77-82.
5. Takeda T, Ishigami K, Hoshina S, Ogawa T, Handa J, Nakajima K, et al. Can mouth-guards prevent mandibular bone fractures and concussions? A laboratory study with an artificial skull model. Dent Traumatol. 2005;21:134-140.
6. Frenguelli A, Ruscito P, Bicciolo G, Rizzo S, Massarelli M. Head and neck trauma in sporting activities: Review of 208 cases. J Craniomaxillofac Surg. 1991;19:178-181.
7. Narimatsu K, Takeda T, Nakajima K, Konno M, Ozawa T, Ishigami K. Effect of clenching with a mouth-guard on head acceleration during heading of a soccer ball. Gen Dent. 2015;63:41-46.
8. Jagger RG, Abbasbhai A, Patel D, Jagger DC, Griffiths A. The prevalence of dental, facial and head injuries sustained by schoolboy rugby players. A pilot study. Prim Dent Care. 2010;17:143-146.
9. Takeshi U, Satoru O, Toshiro K, Hideaki S. A succinct color atlas of oral and maxillofacial surgery 3 edn. Tokyo, Japan: Gakken shoin. 2011:78-79 (in Japanese).
10. Boffano P, Roccia F, Zavattero E, Dediol E, Uglesic V, Kovacic Z, et al. European maxillofacial trauma (eurmat) project: A multicentre and prospective study. J Craniomaxillofac Surg. 2015;43:62-70.
11. Verma S, Chambers I. Update on patterns of mandibular fracture in tasmania, Australia. Br J Oral Maxillofac Surg. 2015;53:74-77.
12. Shimoyama T, Masuda I, Numa T, Horie N. Mandibular fracture with a mouth formed mouth-guard in kickboxing. Dent Traumatol. 2009;25:242-244.
13. Takeda T, Ishigami K, Ogawa T, Nakajima K, Shibusawa M, Shimada A, et al. Are all mouth-guards the same and safe to use? The influence of occlusal supporting mouth-guards in decreasing bone distortion and fractures. Dent Traumatol. 2004;20:150-156.
14. O'Malley M, Evans DS, Hewson A, Owens J. Mouth-guard use and dental injury in sport: A questionnaire study of national school children in the west of ireland. J Ir Dent Assoc. 2012;58:205-211.
15. Hasegawa K, Takeda T, Nakajima K, Ozawa T, Ishigami K, Narimatsu K, et al. Does clenching reduce indirect head acceleration during rugby contact? Dent Traumatol 2014;30:259-264.
16. Maeda M, Takeda T, Nakajima K, Shibusawa M, Kurokawa K, Shimada A, et al. In search of necessary mouth-guard thickness. Part 1: From the viewpoint of shock absorption ability. Ann Jpn Prosthodont Soc. 2008;52:211-219.
17. Westerman B, Stringfellow PM, Eccleston JA. Eva mouth-guards: How thick should they be? Dent Traumatol. 2002;18:24-27.
18. Tanaka Y, Tsugawa T, Maeda Y. Effect of mouth-guards on impact to the craniomandibular complex. Dent Traumatol. 2016;33:51-56.
19. Verissimo C, Costa PV, Santos-Filho PC, Fernandes-Neto AJ, Tantbirojn D, Versluis A, et al. Evaluation of a dentoalveolar model for testing mouth-guards: Stress and strain analyses. Dent Traumatol. 2015;32:4-13.
20. Korioth TW, Hannam AG. Deformation of the human mandible during simulated tooth clenching. J Dent Res. 1994;73:56-66.
21. Maffulli N, Longo UG, Spiezia F, Denaro V. Aetiology and prevention of injuries in elite young athletes. Med Sport Sci. 2011;56:187-200.
22. Musa C, Tasmektepligil MY, Tunc T, Deniz Y. An investigation of the radiological findings of dental and bone diseases related to jaw trauma in combat sports. Turk J Sport Exe. 2016;18:12-17.
23. De Boever JA, Keersmaekers K. Trauma in patients with temporomandibular disorders: Frequency and treatment outcome. J Oral Rehabil. 1996;23:91-96.
24. Hasegawa Y. Fundamental study on the effects of a different form of mouth-guards on modal shape and damping ratio of human dry mandible. J Stomatol Soc Jpn. 1994;61:309-328 (in Japanese).