AN IN VITRO BLUNT IMPACT EXPERIMENT UPON HUMAN CHINS

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In order to investigate the mechanical relationship among the mandible –TMJ– skull during blunt impact, two fresh cadaver heads were impacted at the chins by a blunt body (about 6 kg) with velocity 1.1 m/s and 1.6 m/s. The impact forces were in the direction from the chin and vertically to the junction line of both sides of the condyles. It was found that the impact force-time curves were two peaks profiles. After the impact body contacting the chins, the impact forces rose rapidly to the first peaks (100.3/153.2 N, corresponding to 1.1/1.6 m/s of impact velocity) at 7.25/5.57 ms; then they slid for a while and rose again until reached the higher peaks (171.7/321.7 N) at around 21.1/20.1 ms; the total impact durations lasted about 46.1/42.6 ms. This paper obtained the dynamics characteristics of the mandible – TMJ – skull during blunt impact. It should be useful to further study the mechanical role in the genius TMJ disfunction resulted from facial trauma.

KEY WORDS: impact loading, blunt, temporomandibular joint, chin

INTRODUCTION: Blunt impacts on mandibles often occur in sports, violence, slipping or traffic accident. An impact on a mandible may cause overload on the mandible, the temporomandibular joint (TMJ), and the skull. It is believed that the overload on TMJs is one of the major factors that induces temporomandibular disorders and degenerations, which cause TMJ pain, clicking and/or crepitus, and limitation of mouth opening (Tanaka et al., 2001).
In order to elucidate the role played by the mechanical factor in the genesis of the TMJ joint dysfunction, people have studied the joint loading through two ways. The first was to test by *in vitro* apparatus (mechanical models) and the second to develop mathematical models (Hatcher et al., 1986; Beek et al., 2001). It was reported that degenerative changes could result from a single traumatic event (Kreutziger and Mahan, 1975). An early study of patients with signs and symptoms of TMJ dysfunction showed that 45% of the patients reported prior trauma to the head or neck (Harkins and Marteney, 1985). Recent case studies also showed that TMJ dysfunction is related to history of facial trauma (Macfarlane et al., 2001; Steed and Wexler, 2001). Thus, it is needed to investigate the dynamic characteristics of the mandible-TMJ-skull system during facial trauma. The most primary work might be to investigate the blunt impact on chins.
The objective of our project was to investigate the mechanical relationship among the mandible – TMJ – skull during blunt impact. In this paper, two human fresh cadaver heads had been used in the *in vitro* test of impact on chins and the impact forces were obtained.

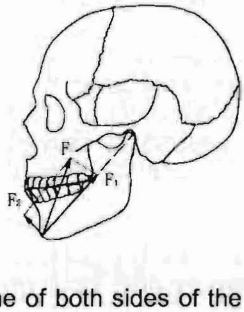

Figure 1 Force analysis during impact on the chin.

Mechanical analysis for experiment: From mechanical point of view, the mandible–TMJ–skull can be considered as a lever system, in which mandible is the lever while temporomandibular joint is the fulcrum. As illustrated in Figure 1, it can be considered that the impact force from the chin upon mandible is composed by two components of forces, provided that the impact force is in the plane parallel to the sagittal plane. One force (F1) is along the chin and vertically to the junction line of both sides of the condyles. Another force (F2) is perpendicular to the first force. It is obvious that F2 has the occlusal effect, which makes bite movement or tendency. The F1 exert force on the glenoid fossa through the temporal bone, condyle, and articular disc. It is clear that F1 represent the dynamic load characteristics of the mandible–TMJ–skull during blunt impact on chins. Therefore, F1 had been examined in our human cadaver impact test.

METHODS: Two fresh cadaver heads without any trauma were used for the experiment (young men, aged 32 and 36). The heads were carefully prepared before the impact experiment. The soft tissue on the posterior-top heads was removed to expose the bony tissue of the skulls. The soft tissue over the maxilla, face, TMJ and mandible were all kept. Some plasters were used to enclose the exposed skulls. The plaster formed two planes (Figure 2). One plane was just perpendicular to the direction of F1, and the other one was paralleled to that direction.

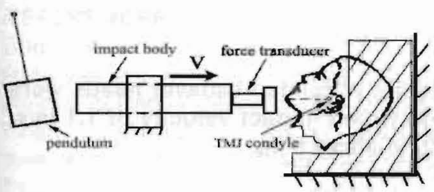

Figure 2 Schematic diagram of the impact test of human cadaver heads. The impact forces were along the chin and vertically to the junction line of the right and left condyles.

A pendulum apparatus was used in the impact experiment (Figure 2). The pendulum could be bolted to set angles and released to impact upon the impact body. The impact body was in cylinder shape with 6 kg in mass. The impact body exerted force on the chins through a piezoelectric transducer (5112, No. 702 Institute of Astronautics, Beijing, China) and a steel plate (0.2 kg). The piezoelectric force transducer is connected with an amplifier.

The two prepared cadaver heads were impacted separately as following processes. First, the cadaver head was mounted on the platform beside the impact apparatus (Figure 2). Then, the impact body with velocity of 1.1 m/s or kinetic energy of 3.6 J impacted the head for three times. Finally, impacted with 1.6 m/s or kinetic energy of 7.7 J for three times. The impact force signal from the amplifier was recorded by a tape recorder (SONY A1021, Japan). A cathode-ray tube oscillograph (SR54, Ningbo Wireless Factory, Ningbo, China) was also used for monitoring the force signal.

After the test, the impact force signals were sampled at 54 microseconds interval (about 18.5 kHz) by a signal processor (7T17, NEC Sanei, Tokyo, Japan) from the tape recorder, and then input to an IBM PC. The data were filtered using a low-pass (180 kHz) digital FFT filter. Inspection showed that this filtering did not alter the force-time curve significantly.

RESULTS: As shown in Figure 3, the force-time curves were two-peak impact profiles. When the impact velocity was 1.1 m/s, the impact force rose rapidly to the first peaks (Fs, 100.31±13.44 N) at around 7.25 ± 1.36 ms (Ts) after contacting with the impact body; after the force reached the first peak, it slid for a while and then rose to higher peaks (Fp, 171.69 ± 23.08 N) at around 21.14 ± 1.96 ms (Tp); the impact duration (T) was about 46.08 ± 0.95 ms (Tab 1). When the impact increased to 1.6 m/s from 1.1 m/s, Fs and Fp increased about 53% and 87% respectively; Ts and T decreased about 23% and 7% respectively; but Tp was nearly same (Tab 1).

Table 1 Results of impact tests (mean±SD, n=6).

Group	Ts(ms)	Fs(N)	Tp(ms)	Fp(N)	T(ms)
V_1=1.1m/s	7.25±1.4	100.31±13.4	21.14±20	171.69±23.1	46.08±1.0
V_2=1.6m/s	5.57±0.4	153.21±20.0	20.17±1.7	321.68±35.2	42.59±1.7
P	0.016	0.00031	0.38	0.0000054	0.0014

Notice: Fs: the first peak of the force, at which force began to slide; Ts: time to the first peak force; Fp: the maximum force; Tp: time to maximum force; T: total time duration of the impact (see Figure 3). P: A paired- sample t-test was used to compare the V_1 and V_2 group.

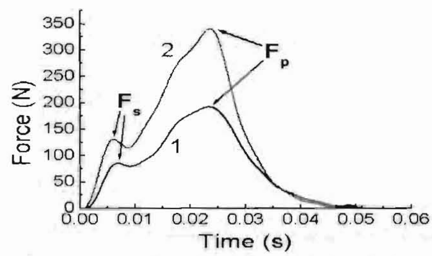

Figure 3 The impact force-time curves upon the chins of human cadaver heads were two peaks (Fs and Fp) profiles. Line 1 corresponds to the impact velocity of 1.1 m/s, while line 2 to 1.6 m/s. The mass of the impact body is about 6 kg.

DISCUSSION: This study provided the dynamic characteristics of impact force of the mandible – TMJ – skull system during blunt impact. The impact force curves were not as expected, bell-like curves with only one peak, but two peak profiles. We think that the extremely complex structure of the TMJ caused the impact force curves in two peak profiles. The TMJ consists of the condyle, disc, and the fossa-eminence complex. The fossa-eminence has over large space to contain the disc and the condyle. This complexity enables the condyle to move in translation and rotation. In our experiment, the impact forces were along the chin and vertically to the junction line of both sides of the condyles. The mandibles could only move in translation. We suppose that the mandibles began to translate with the condyles sliding in the fossae when the impact forces reached the first peaks. In slide period, the forces decreased. After the slide period, the impact forces increased again and get to the second peak.

The slide movement of the condyle is important for the mandible – TMJ – skull system to protect against impact from the chin. The translations of the mandibles increased the impact duration and decreased the maximum forces. Our paralleled impact experiment upon goats' chins indicated that the impact profile is in one-peak profiles and its maximum force was much greater than the maximum forces of the human cadavers. For example, when the impact velocity was 1.1 m/s, the maximum force of the goat was about 380 N, which was more than 2 times of the human cadaver heads. But the impact time was decreased to 32 ms. It could be conclude that the mandible – TMJ – skull complexes of human being have cushioning effect against impact from chins.

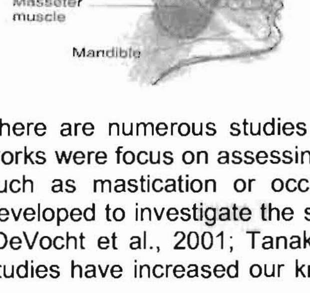

Figure 4 Schematic diagram of the anatomy of the mandible – TMJ – skull. The TMJ consists of the condyle, disc, and the fossa-eminence complex.

There are numerous studies about biomechanics of the mandible, TMJ, and skull. Early works were focus on assessing the joint loading during physiological movements of the jaws, such as mastication or occlusion. Recently, several finite element models have been developed to investigate the stress distributions during physiological movements of the jaws (DeVocht et al., 2001; Tanaka et al., 2001; Chen et al., 1998; Beak et al., 2001). Those studies have increased our knowledge of the mechanical environment around the TMJ and

the mechanism of genius of the TMJ disfunction. However, there is very few studies related impact in the maxilla and mandible. Tan et al. (2002) investigated the biomechanical changes during penetrating impacts upon animal maxilla and mandible. Howard et al. (1998) studied the mandible dynamics generated by 'whiplash' in traffic accidents.
This paper is the first that investigate the dynamic relation among mandible, TMJ and skull during blunt impact on chins. Also, the first getting the transient impact forces during impact on chins. It was found that the impact force curves were two peak profiles. We thought the complex anatomy of the TMJ cause such dynamics characteristics. This is a fundamental step to further understand the mechanism of TMJ disorders induced by facial trauma caused by sports or other occurrences.

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