# Analysis on Dynamic Characteristic of Pig Skin to Obtain Scientific Knowledge on Safe Design for Preventing Laceration.

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Abstract: Lacerations occur frequently in common environments, however the mechanisms by which they are generated remain unclear. This makes it difficult for designers to create products that can prevent lacerations. Although a significant number of studies have dealt with injury prevention from the standpoint of avoiding bone fractures, lacerations have yet to be thoroughly investigated and a scientific approach to laceration prevention is urgently required. In this paper, we describe analysis of the dynamic characteristics of pigskin, which is one of human-skin-like materials, in order to understand laceration generation mechanisms and assess the risk of laceration quantitatively at designing common products. According to statistical analysis using injury surveillance data, a typical situation involves a collision between a victim's head and the edge of an object, such as a table, chair, bathtub, or other such item. Accordingly, we conducted experiments using a drop impact tester to determine the dynamic characteristic of pigskin, which is a substitute for human skin, when it collides with various materials. This paper reports our experimental results and discusses scientific knowledge for designing product safety features by clarifying conditions that have effect on laceration.

***Key words: Design for Safety, Kids Design, Laceration, Risk Assessment***

## 1. Introduction

In product design, usability, safety and freshness are important. Until now, the safety of product actually using in common environments has become important. Since injuries occur daily in most common environments, prevention has recently become a pressing global concern[1], so scientific product design in order to prevent it has been required. However, while injury prevention requires an understanding of injury generation mechanisms, many types of injuries have yet to be investigated. For example, while a significant number of studies have investigated injury prevention from the standpoint of conventional bone fractures and brain injuries[2][3][4], lacerations caused by human body collisions with the corners and edges of consumer products have not been thoroughly investigated. Furthermore, although the material properties of children's skin have been measured by tensile testing and other means[5][6], laceration mechanisms remain unclear. Thus, the development of standards based on scientific evidence to support laceration prevention in product design stages is urgently needed. In this research group is to promote the study of injury prevention engineering for product design. We take up the issue of lacerations that occur frequently in most common environments, and consider how to alleviate lacerations.

As described in Section 2, lacerations are caused by collisions between a body part and the edges of items, such as tables, chairs, bathtubs, and so forth, it may be possible to prevent laceration generation by changing the shape and material used in the edges of various products. In this paper, we report on experiments conducted using a drop impact tester in order to determine the relationships among various design parameters, such as the shapes and materials used to produce edges.

## 2. Statistical Injury Data for Understanding Laceration

We statistically analyze the children's injury data collected by National Institute of Advanced Industrial Science and Technology(AIST) and National Center for Child Health and Development(NCCHD) [7][8].

Figure 1 shows the incidence of each type of laceration accident. As can be seen in this figure, of those accidents that result in lacerations, falls account for 68%, and collisions account for 22%. In general, lacerations are caused by the collision of a human body moving at high speed with an object, or vice-versa. Accordingly, in order to clarify laceration-generating mechanisms, it is necessary to measure the dynamic material properties of the laceration injury site.

Figure 2 shows the areas of the human body that are most frequently subject to laceration injuries. The red area indicates high frequency injuries while the blue area indicates low frequency injuries. As can be seen in Figure 2, lacerations occur most frequently at the forehead and the jaw areas of the human head, thus indicating that such injuries occur most frequently on skin that is in close proximity to bone. In contrast, such injuries are relatively uncommon on areas of the body where significant amounts of subcutaneous tissue exist.

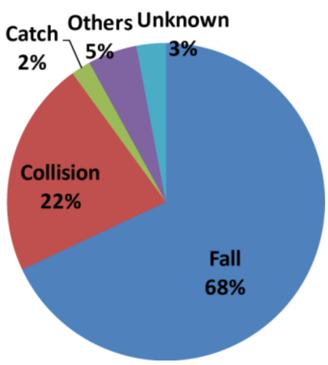



Fig.1 Laceration accidents by type

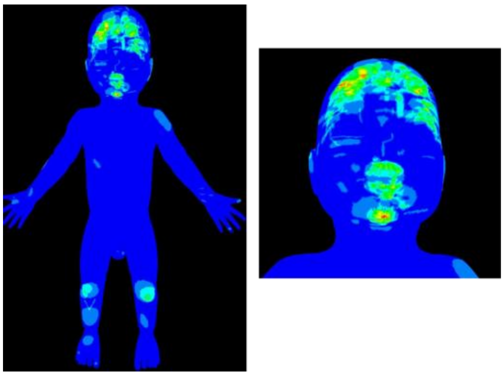


Fig.2 Human body injury sites

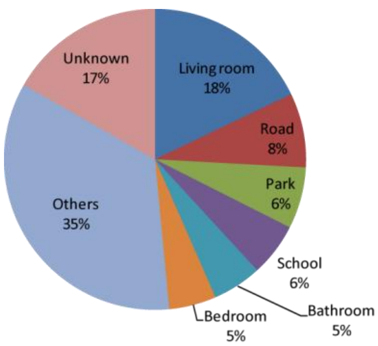



Fig.3 Laceration accident occurrence locations

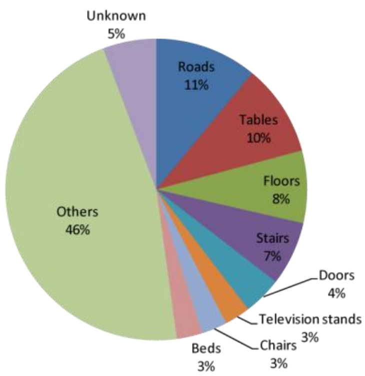



Fig.4 Products and environment associated with laceration accidents

Figure 3 shows the locations where laceration accidents most commonly occur. This graph indicates that such injuries occur most frequently in living rooms, which are spaces in which children spend significant amounts of time, and where various furniture items that children might collide with exist.

Figure 4 shows the objects and environments related to laceration occurrences. This graph indicates that the ground, such as roads, floors, and stairs, along with the corners of items such as tables, stairs, chairs, and doors are commonly associated with laceration accidents, thus suggesting that lacerations are also related to the shape and material of the items struck, as well as other collision conditions such as impact velocity.

## 3. Drop Impact Tester for Understanding Laceration Mechanism

We developed a drop impact tester for understanding laceration generating mechanism. Figure 5 shows the drop impact tester, which consists of a metal sphere with a radius of 75mm covered with a thin skin-like material that is placed at the bottom to simulate a human head. The skin is attached to the sphere as shown in Fig. 5. Lacerations are inflicted when the simulated head is hit by edge members with various radius R and chamfer C values. A high-speed camera positioned nearby is directed at a prism inserted inside the simulated head, thus allowing direct-observations of the laceration occurrences.

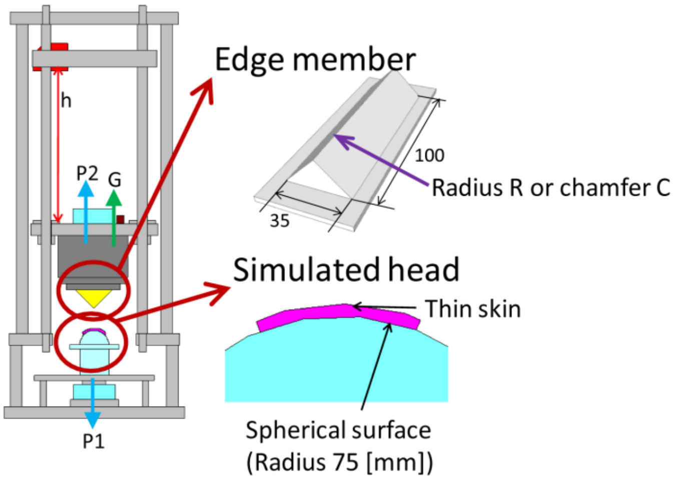



Fig.5 Impact drop tester

## 4. Impact Experiments

In this section, we describe the artificial laceration generation experiments conducted using the drop impact tester. In these experiments, pigskin was attached to the simulated head as a substitute for human skin. Three materials with different hardness levels: steel, medium density fiberboard (MDF), and MDF covered with silicone rubber, were selected to provide the target edges, as shown in Figure 6. Their shapes were designated as R2, R4, R6, R8, R10, and C5. For the C5 specimen, in order to compare the effect of the impact angle, experiments were conducted under two installation angle conditions, θ=15° and 0°, as shown in Figure 7.


Fig.6 Edge members

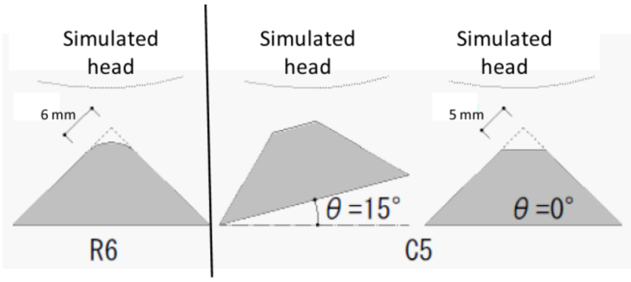



Fig.7 Installed edge member angles

Figure 8 shows examples of pigskin damaged by impact tests. For the C5 specimen, it can be seen that the skin suffered more severe damage under the condition of θ=15° than θ=0° for all tested materials.

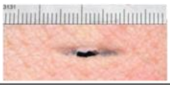
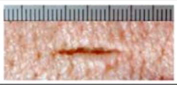
| | Steel | MDF | Silicone rubber |
|---|---|---|---|
| R2 |  |  |  |
| C5 θ=15° |  |  |  |
| C5 θ=0° |  |  |  |

Fig.8 Examples of pigskin lacerations under various conditions

## 5. Experimental results and discussion on laceration prevention

During our experiments, changes were made to the shape and height of the impact member in order to clarify the probability of laceration occurrence to pigskin. Figures 9 to 11 show the relationships between laceration occurrence, impact speed, and edge shapes in the cases of steel, MDF, and silicone rubber, respectively. Generally speaking, as the radius increases, higher collision speeds are required to generate lacerations. For specimen C5, a laceration in case of θ=15° can be produced at a lesser impact speed than θ=0°.

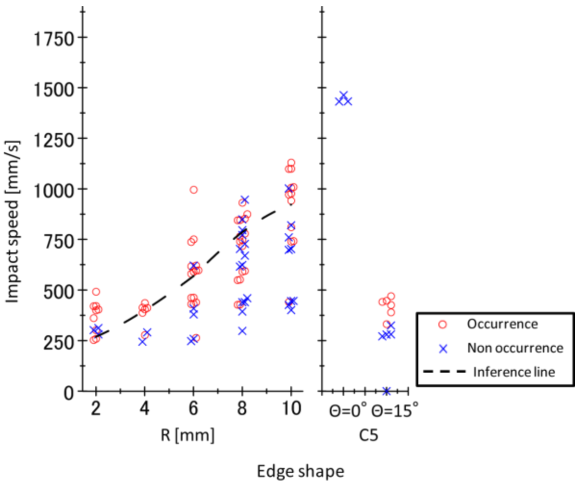



Fig.9 Laceration occurrence on steel edge members

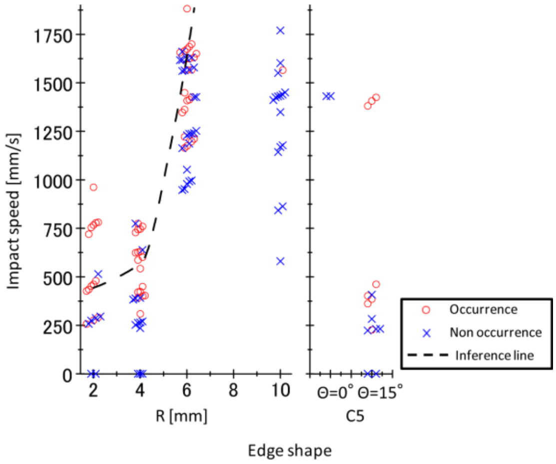



Fig.10 Laceration occurrence on MDF edge members

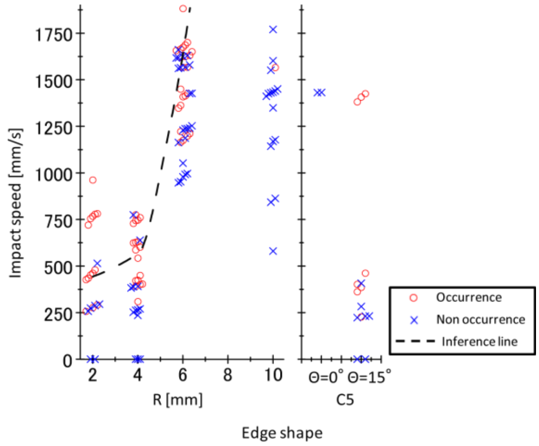



Fig.11 Laceration occurrence on MDF edge members covered with silicone rubber

Figures 12 to 14 show the laceration occurrence probability distributions for steel, MDF, and silicone rubber covered MDF specimens under various collision speed and edge member shape conditions. These figures indicate that steel is the most dangerous material, MDF is the second most dangerous, and that silicone rubber covered MDF is the safest. In case of MDF, it was found that if the edge radius is less than 6 mm, the laceration hazard is quite high. While, conventionally speaking, product designers empirically know that a harder material and a sharper edge are more dangerous, a more precise understanding of the probability distribution of laceration occurrence allows them to discuss product safety quantitatively.

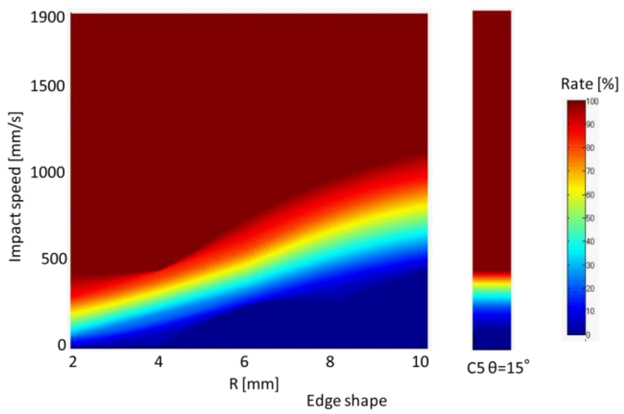



Fig.12 Probability distribution for laceration occurrence (Steel)

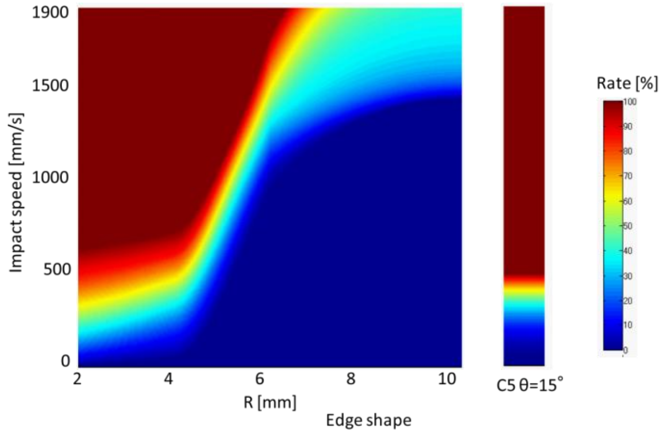


Fig.13 Probability distribution for laceration occurrence (MDF)

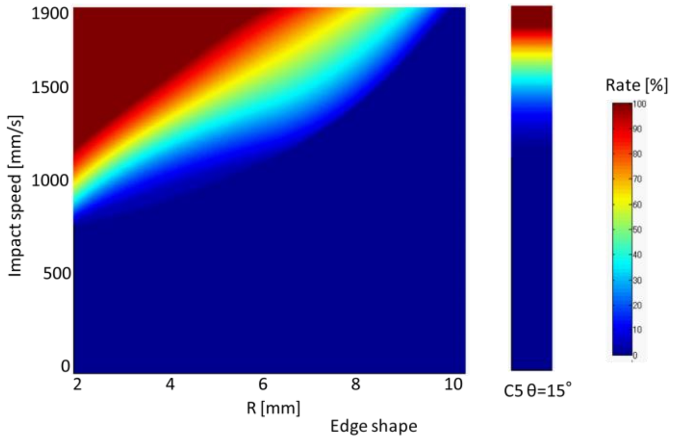


Fig.14 Probability distribution for laceration occurrence (MDF covered with Silicone Rubber)

## 6. Conclusion

In this study, we investigated the conditions that affect on the occurrence of laceration. We developed a drop impact tester for experiments. Using this tester, we experimented with pigskin specimens as substitutes for human skin. We examined the relationships among safety, material, and edge shape by creating probability distribution diagrams regarding laceration occurrences cased by collisions with steel, MDF, and silicone rubber edges. We clarified that use of MDF can significantly improve product safety when the radius of an edge is greater than 6 mm, and that covering an edge with soft material, such as silicone rubber, is also effective.

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