Crash Impact Dummies adapted to People Affected by Osteogenesis Imperfecta

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I. INTRODUCTION

Osteogenesis Imperfecta (OI) is a genetic disorder characterised by increased bone fragility and low bone mass 0, commonly known as a brittle bone disease. People affected by OI are generally characterised by a short stature or small body and a relatively large head.

Due to their unusual body proportions, people affected by OI may have difficulty obtaining proper safety restraint during vehicle travel. Moreover, the current crash test dummies do not adequately represent this population, making it difficult to develop and assess appropriate restraints. Severely affected people suffer significant body deformities and have body proportions that differ substantially from those without OI. Publically available anthropometric data for this population are very limited and only consider variables such as stature, total body mass, head circumference and age.

Consequently, the aim of this investigation is to develop an anthropometric database of people affected by OI in order to obtain the geometrical parameters and segment mass distribution for physical and computational anthropomorphic test devices. The overall objective is to manufacture two adapted dummies that represent such anthropometry. In a later stage, more detailed anthropometry will be collected to study injury limits and propose injury criteria for use with these adapted dummies.

II. METHODS

An anthropometric study of the most important aspects of the disease from the passive safety point of view was conducted. An anthropometric protocol based on *Volume II: Biomechanics Tests* (NHTSA) 0 was developed and adapted to the needs of people affected by OI. The anthropometric sample is made up of 36 volunteers, and 64 variables have been registered for each volunteer (lengths, breadths and circumferences from all the body segments). Due to the anthropometric heterogeneity, a ratio related to stature is applied to all the measures registered. This normalisation allows for comparison between the subjects and calculation of the average in order to define two models that represent people with moderate or severe OI symptoms.

The normalisation process was based on anthropometric data for unaffected children gathered by UMTRI 0. These relationships were used to scale each variable with regard to stature. A constant body mass index (BMI) was assumed for each subject. The mass distribution was estimated using software based on the procedure reported by Obergefell for the *GEBOD-IV* software 0.

Two adapted dummies were created by assembling parts from different sized ATDs. Parts used are from the new Q family units, ranged from the Q1 up to the Q10 and also of the Hybrid-III 6YO. Adaptation parts were manufactured to allow the assembly of elements from different dummy sizes at the joints when it was necessary. The articulations ranges of movement are respected by these joining parts. Also, special purpose layers made by silicon, fabrics and lead balls, were made to adjust the mass of the body segments of the adapted dummies, to the segments masses of the models obtained by calculation.

Three child restraint systems (CRS) were tested (total 16 tests), with those adapted dummies and the standard Q dummies (Q1.5 and Q3). Eight frontal and eight side impact tests were performed using a sled bench according the prescriptions of the UNECE Regulation 129. Both the standard dummies and the adapted ones were fitted with accelerometers at head, thorax and pelvis; three spine load cells (when it was possible to install them) and thoracic deformations (front or side according the test impact performed). The influence of the deformities on the restraint performance was analysed, along with ATD readings related to injury criteria.

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III. INITIAL FINDINGS

The main results of this study are as follows.

- Anthropometric database of people affected by OI (36 subjects).
- Mass distribution between the body segments (total 15 segments: head, neck, upper limbs …) using mathematical models (collaboration with UMTRI tools) for each defined model.
- Two STL models of subjects affected by OI Type III.
- Geometrical definition and mass distribution for manufacturing two impact dummies adapted to people affected by OI.
- Two physical prototypes using Q-dummy segments.
- Data registered by the adapted dummies during the impact tests.

Figure 1 shows the two dummy prototypes and a STL model of a subject affected by OI Type III (those with severe symptoms). In Fig. 1(a) is described the parts of the different models or adapted dummies, which are made up using the Q-dummy's family and the Hybrid-III 6 YO. Both adapted dummies are also ballasted in those segments, which is necessary due to the mass distribution previously calculated. The Model 1 represents those with severe symptoms, while the Model 2 represents those with moderate symptoms. On the other hand, in Fig. 1(b) 400 slices were obtained, using *Philips Brilliance 64-slice CT scanner x 0.625 mm*, in order to build a skeleton bone structural model based on two subjects affected by OI and to study the injury limits by using FE models.
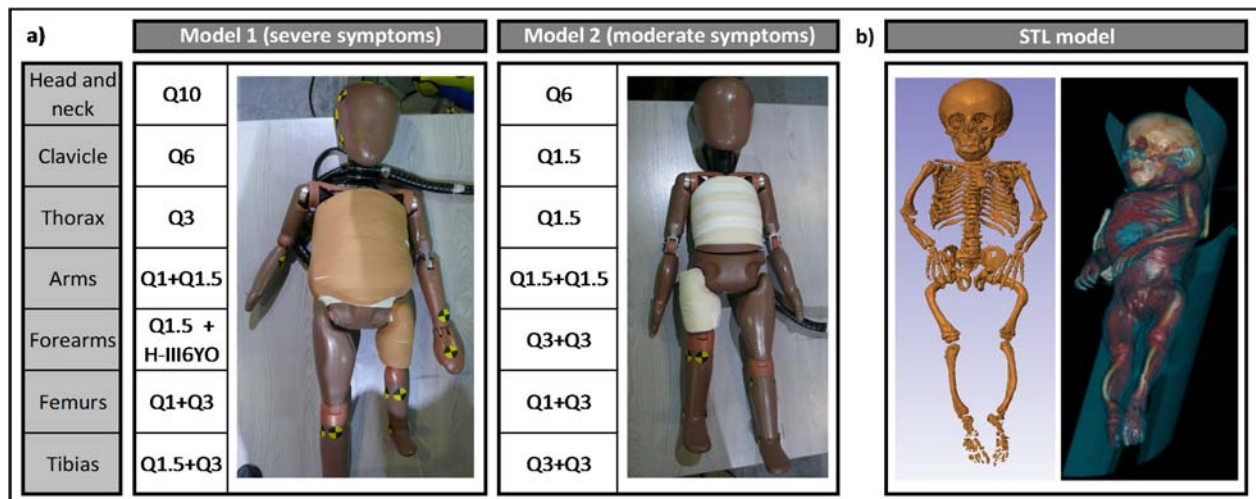

Fig. 1. (a) Two prototypes of adapted dummies; (b) STL model of a subject affected by OI Type III.

IV. DISCUSSION

At the present time, studies about the passive safety of people affected by OI are very limited, so this research is innovative and necessary. Two dummies were adapted to represent people with this rare disease. The study concludes that it is possible to obtain a modified dummy combining several parts of standard dummies, and with these results replicate the anthropometry and mass distribution of people affected by OI or other diseases, such as dwarfism. Through these two prototypes of adapted dummies it will be feasible to study restraint performance in an impact test using alternative restraint systems (such as CRS with "Special Needs Restraint"). Through these means, objective data are obtained about the influence of deformities during the lateral and frontal impact in the restraint devices tested. Using the CT obtained from individuals affected by OI, it will be possible to develop a FE model to conduct computational simulations of restraint performance for this population.

V. REFERENCES

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