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Developing prototypes of the assistant opener of packaging for consumer accessibility

ABSTRACT

The purpose of this research was to focus on the design of packaging openers for consumer access to the contents. The packaging opener was created to make opening easier and safer. In this study, online questionnaires were used to investigate the problems and solutions of user experiences when opening packaging. According to the findings, a major issue among the responding participants is that they should have a strong hand force. However, the hand force not only had enough energy to open the packaging, but it was also unable to open the closure at the specified location. When participants encountered opening problems, they preferred to use an assistant tool rather than ask for assistance. The risk of packaging materials, scissors, knives, and wrist and finger twisting occurred during opening packaging. According to the respondents' experiences, the four functions of the packaging opener were integrated together for the corrugated box, ring-pull a can, lug cap closure, and flexible packaging. As a result, the newly designed packaging opener required less opening force, a safer hold, and optimized hand ergonomics. The attractive configuration and comfortable grip were also important factors to consider when designing the packaging openers in this study. Opener prototypes were modelled using SolidWorks and were formed by a 3D printer. The FSUDE system was employed to evaluate the functions, safety, usability, design, and engineering of all prototypes. Based on the results of this study, form, dimension, surface, friction, and grip posture were factors affecting torque force exertion, slitting and cutting force, and openability of consumers.

KEY WORDS
Opener, opening packaging, product design, opening assistant tool

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Introduction

The COVID-19 outbreak has changed the lifestyle of consumers. Over recent years, they are concerned about health care, and avoiding the risk of infection; therefore, online shopping is one of the interesting choices due to the avoidance of contagious diseases, convenient purchases, and fast delivery. To promote online shopping, the strong packaging of the product is essential so that the products do not get damaged during shipping to the customers. The requirement for durable packaging is for the customer’s confidentiality, product distribution, and product storage. Unfortunately, these packages cause problems opening for customers. Opening packaging with knives, scissors, teeth, and hands is not convenient and leads to injury to the hands and fingers. Many studies have reported effective packaging opening methods in various groups. Among over 60-year-old consumers, they encountered problems with the ergonomics in terms of size, shape, and opening and closing features; therefore, they desired changes in food packaging (Świda et al., 2019). Based on a study by Bell, Walton & Tapsell (2016), a number of the elderly staying in hospitals were unable to open the packaging due to the dexterity of hand function. Daphne et al. (2014) investigated whether packaging can cause problems in daily practice, especially among older people with medicine packaging. The findings indicate that pharmaceutical manufacturers needed to understand the effects of packaging and how to cause problems for patients. In other words, the opening problems of flexible packaging were dependent on a strong heat seal, film thickness, limited force, and user dexterity of both genders or ages (Nilmanee et al., 2018). For safety issues, Cengiz & Melvin (2010) reported that certain types of packaging, such as tinplated steel cans, cause injuries when consumers attempted to open them. In addition to the sharp edges of the packaging, objects used to open the packaging also contribute to injuries. In some cases, the opening tools are the sources of injuries. For instance, the most difficult container is a can that needs a tool to open. Impaired physical and cognitive functions influence the elderly's ability to open medical containers (Beckman et al., 2005). They also reported that they were unable to open the screw cap bottles, bottles with a snap lid, as well as blister packs. Parkinson's disease, rheumatoid arthritis, cognitive impairment, and impaired vision were associated with a decreasing ability to open the packaging. In 2017, Giana & Daniel (2017) reviewed the relationship between older patients and the impact of packaging on medical usage. According to the reviews, the studies can be divided into two following ways. The first method involves considering opening package problems due to physical functionality and user capability, whereas the other studies focus on medical management, packaging, and user orientations.

Ward, Buckle & Clarkson (2010) found that patients taking methotrexate had several difficult experiences with medical packaging, which might increase the risk of error doses. In addition to opening packaging problems, instructions on labels are important to ensure that patients take the right doses and are also available to open the package. As a result, the packaging and labels should contain distinctive information and comprehensible opening instructions. Easily opening packaging is necessary for consumer accessibility, either with bare hands or with a packaging opener. To understand essential grip and finger movements, Kamat et al. (2010) demonstrated pain frequency and pain level during gripping activities. The results indicated that the distribution forces depended on the styles of grip, such as a comfortable grip and a power grip. The grip style and finger position applied different pressure and distribution forces. In 2011, Chavalkul, Saxon & Jerrard (2011) indicated the engagement of hand positions, hand actions, hand direction and adequate opening for novel packaging. According to ergonomics of hands, Rowson & Yoxall (2011) showed a further study whereby consumers were asked to apply the most common grips with a torque measuring device. Different grip styles were seen to produce different peak torque values. Using a jar simulation, Huang et al. (2014) investigated the posture effect on finger behaviour during jar opening. The resultant force of the thumb produced greater tangential torque contributions, and the index-middle had similar torque contributions. Yoxall, Gonzalez & Rawson (2018) investigated finger motion coordination during packaging interaction. The results showed that finger correlations were relevant to the dexterity of pack opening. The packing format was related to finger movement. Therefore, the purpose of this paper is to explore the concept of opener improvement for functional safety and easy opening with corrugated boxes, ring-pull a can, lug cap closures, and flexible packaging. The packaging openers were designed based on attractive form, suitable packaging dimension, and hand ergonomics, which supported surface friction and force exertion. Furthermore, the packaging opener prototypes were also measured by human force during interaction with packaging and were evaluated for user satisfaction.

Material and Methods

Questionnaire of packaging opening problems

In this study, eighty-four Thai people were consumers in a city in southern Thailand and participated using the convenient sampling technique. The online questionnaire was divided into the following 2 sections. The first section asked for general information about the participants, and the second section related to opening problems when they encountered specific packages such as a corrugated box, flexible packaging, a ring-pull can, and a glass jar with a lug cap.

Conceptual development of equipment prototypes to aid in opening packaging

The designed prototyping of opening assistant tools was based on function, safety, usability, design, and engineering systems (FSUDE). A function of the user was improved by cutting flexible packaging, slitting corrugated boxes, lifting the easy-pull ring of a can, and gripping and twisting the lug cap and screw cap. The easy-grip, ergonomics, and universal were applied for safety, while usability was referred to as the openability of consumer accessibility, finger coordination, and grip posture on packages. The designed opener prototypes were dependent on the identification of form, shape, ratio, dimension, the friction of the surface, and satisfaction evaluation. The last one was related to engineering as human force measurement. Based on the grip postures of humans when consumers open the packaging, the concept of the prototype's design was divided into five following patterns. The mockup of each object was modelled using SolidWorks software, and all mockups were built layer by layer using 3D printing filament technology for making the prototype (Pro 2Plus, Raise3D printer, United States). Before using the 3D printer, all objects as mockups were converted to the STL format with the open source Ideamaker software to gcode format. Polylactic Acid (PLA) is a filamentous material used for forming rapid prototyping objects.

Opening force measurement and satisfaction evaluation

For measuring opening force and evaluating user satisfaction, 28 healthy consumers participated in the test. Before testing of slitting maximum force measurement on the metal plate and torque force exertion on the lug cap, each participant was trained for each specific handle style of the manipulated position on five opener prototypes with four packaging categories. In the first section, all participants handled naturally on five opener prototypes at specific grip postures with their right hand and left hand. Then each subject had to test the slitting force exerted on a 50-mm-diameter piece of paper until it split. A piece of paper was fixed on the metal circle plate with a digital force gauge as shown in Figure 1 (Desik DS-50, Germany).

» **Figure 1:** *Digital force gauge and grip posture of force measurement*

Maximum force data for each subject were recorded. In the second section, a torque meter (Mechanical Torque Meter: Tohnich, Japan) was employed for measuring the maximum torque force for human opening on a vacuum jar lug cap of 60-mm in diameter with the opener prototypes and without a tool for a convent hand, either precision grip or power grip using in accordance with ASTM D3192 (Figure 2).

» **Figure 2:** *Mechanical torque meter and grip posture of force measurement*

All participants were determined to be in the typical experimental standing postures. For the section on satisfaction evaluation, after the participants were done completely using the openers with corrugated boxes, ring-pull a can, lug cap closures, and flexible packaging. All participants needed to assess the prototypes of the issue lists, including the ergonomics, geometry, utility, safety, commercial, and design, using a rating scale of 1–5.

Results and Discussion

Participant experiences of opening for packaging

A total of eighty-four Thai participants were asked to complete the questionnaire online. The female and male participants in this study were 81% and 19%, respectively (Table 1). The mean weight and height of participants are displayed in Table 1. The data shows the percentage of participant responses that encountered problems when they opened the packaging (Figure 3).

According to the findings, more than 40% of respondents effectively related the problems to human force and durable packaging closures. In addition, participants pointed out that they preferred the tools to open the flexible packaging and corrugated boxes due to cohesion. Figure 4 presents the risk and the painful experiences of the participants when they encountered difficulty in opening packaging. Packaging material that was sharp and strong, dangerous from using a knife or scissors, and injuries to fingers and wrists were often caused by the barrier to consumer accessibility of the products in the survey.

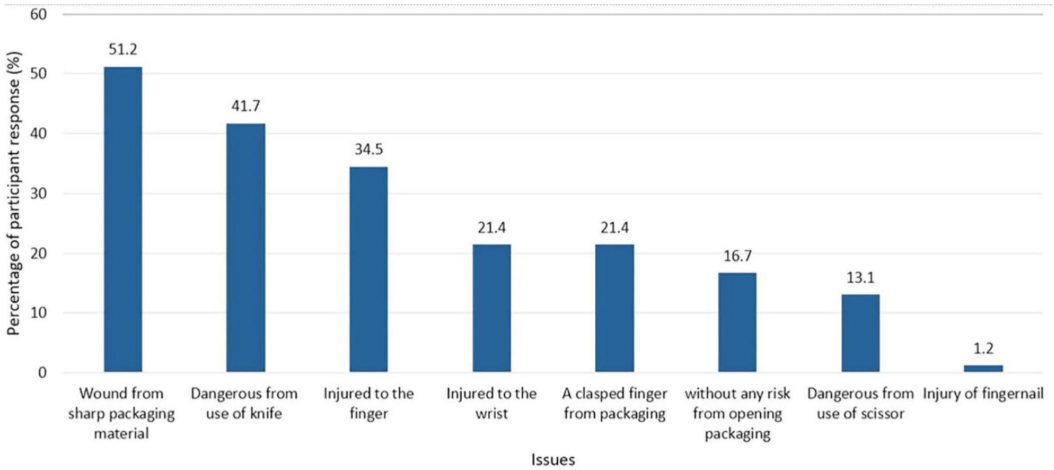
Table 1

Description of Thai participants

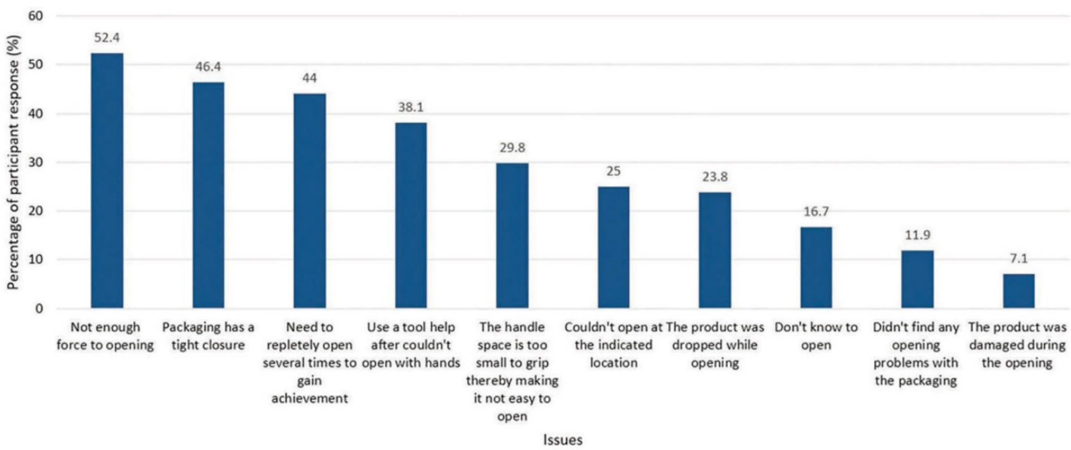
Participant information	Frequency % (n)
Gender	
Male	19 (16)
Female	81 (68)
Age group (years)	
>20	21.4 (18)
21-30	54.8 (46)
31-40	8.3 (7)
41-50	6 (5)
51-60	10.7 (9)
Weight (kg)	
40-45	20.2 (17)
46-50	14.3 (12)
51-55	13.1 (11)
56-60	19 (16)
>60	34.5 (29)
Height (cm)	
141-150	13.1 (11)
151-160	44 (37)
161-170	32.1 (27)
171-180	10.7 (9)
>180	2.4 (2)

Conceptual design of the packaging opener stage

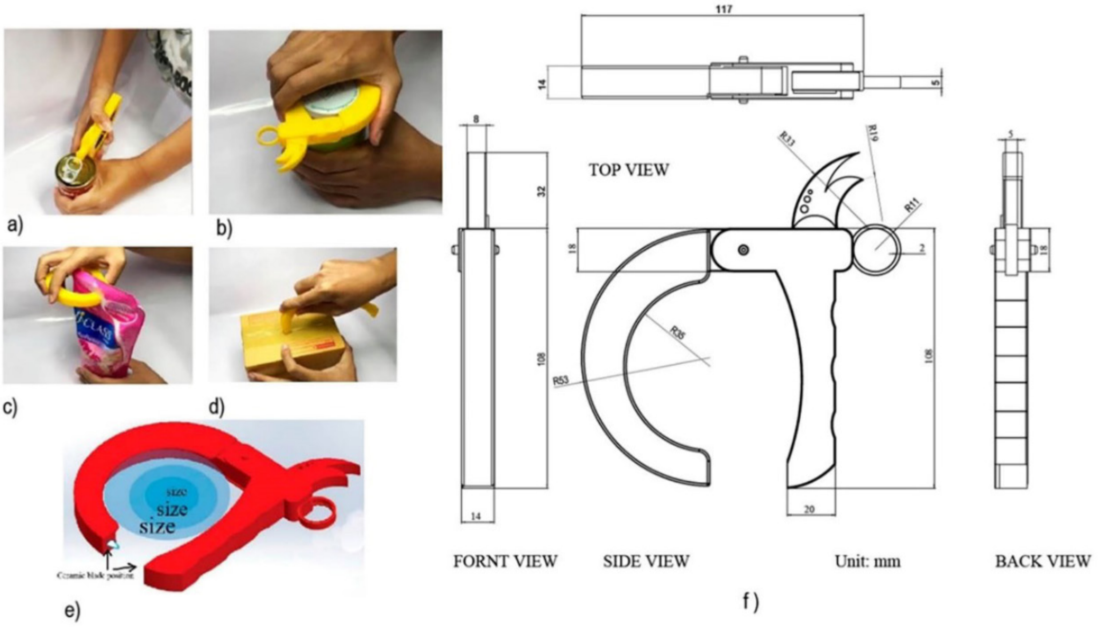
Many factors influence the human capability of a safe and easy opening process on packaging, including opening posture, ergonomics, force increase, hand physicality, and so on. As a result, function, safety, usability, design, and engineering (FSUDE) were based on the improvement of the conceptual design of user-friendly open-aided tools. The concept of the opener design is to integrate four functions of opening into a packaging opener. In this study, compatibility of multi-function in packaging opener design was associated with distinguishing the utilities of human ergonomics for cutting, slitting, twisting, and pulling through the designs. The designed opener prototypes were then further classified into five features. The dimensions and shape of each prototype were identified in accordance with hand and finger size as well as grip posture styles during the opening of corrugated boxes, flexible packaging, lug cap, and a can. The first feature of the prototype in Figure 5 depicts the grip feature while using an opener with four functions on four different types of packaging. Figure 5a is typically used for a handgrip on the curve-shaped opener to pull



» **Figure 3:** *Percentage of participant response for issues with using and opening packaging*



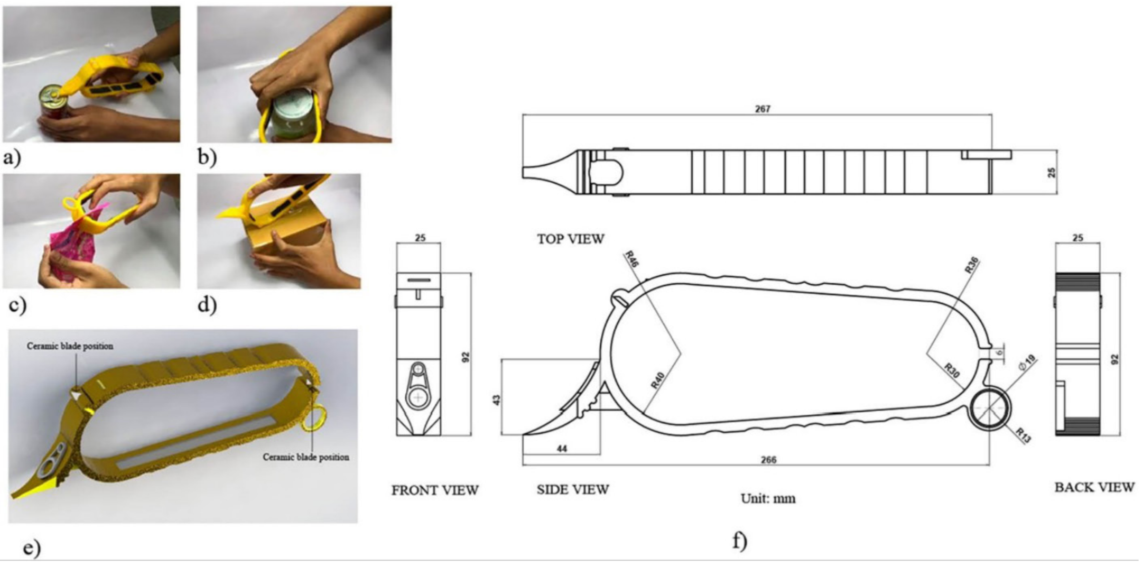
» **Figure 4:** *Percentage of participant response effecting with packaging opening problems*



» **Figure 5:** *Grip posture features on 4 packaging with prototype 1*

up a ring on top of a can. Figure 5b shows the spherical grip of an opener applied to a vacuum jar lug closure that is suitable for jars of various sizes and ease of grip. Furthermore, the effective friction was increased by placing rubber coaster pads with an adhesive liner on the inside surface of the container lug closure surface. Figures 5c and Figures 5d display grip positions for cutting flexible packaging and slitting cohesive tape on a box. Two ceramic blades were inserted into specific locations on the prototype. The packaging opener of type 1 was designed with two elements: a ring-pull can handle and a semicircular shaped part. Both elements were connected by functions to provide a comfortable hand grip and finger coordination. Figure 5e depicts the prototype features and position of the ceramic blade. Figure 5f illustrates a fabrication drawing of the elements.

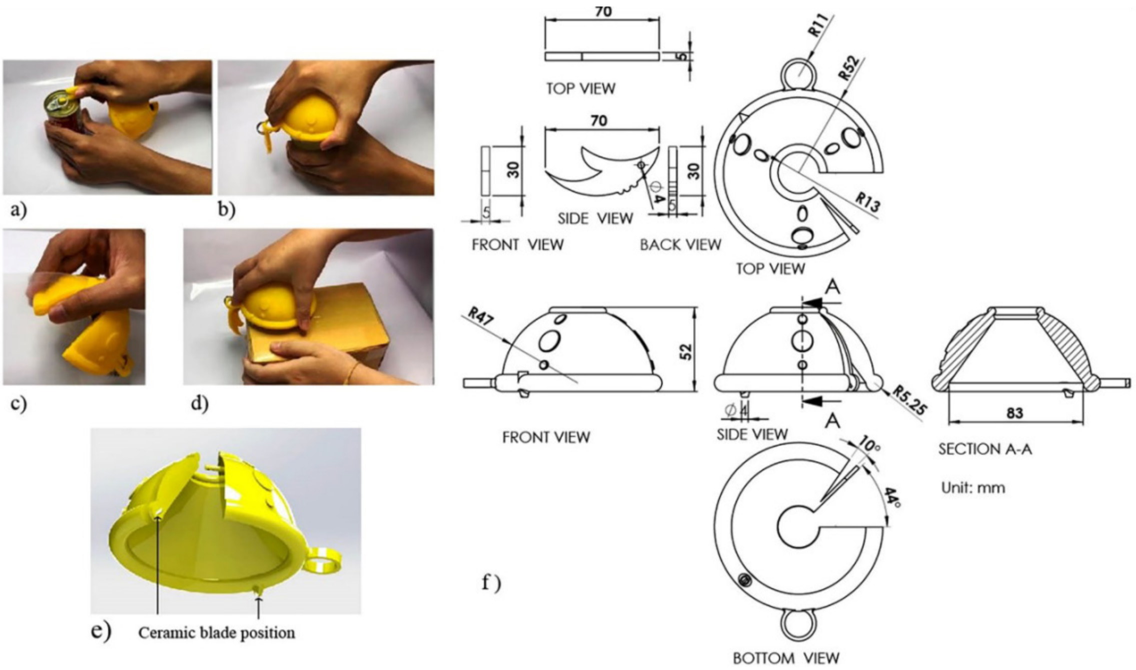
Figure 6 shows the grip features of the opener in the second prototype that were created based on the stage of interaction between human opening posture manipulation and packaging characteristics. The prototype was a shaped-curve design in one piece. The potential of the handgrip was related to the dimensions of the palm, finger, and packaging. The designed position was appropriate for the four packaging types' opening functions. The small shaped curve was designed as the can opener to pull up on the easy opening ring and is placed at the front of the prototype (Figure 6a). In addition to the jar opener, the spherical grip on the lug closure of the cylindrical container had different dimensions (Figure 6b) because the rubber coaster pads with adhesive liner had effective friction to increase between the closure and the rubber surface when consumers twisted a bottle or jar.



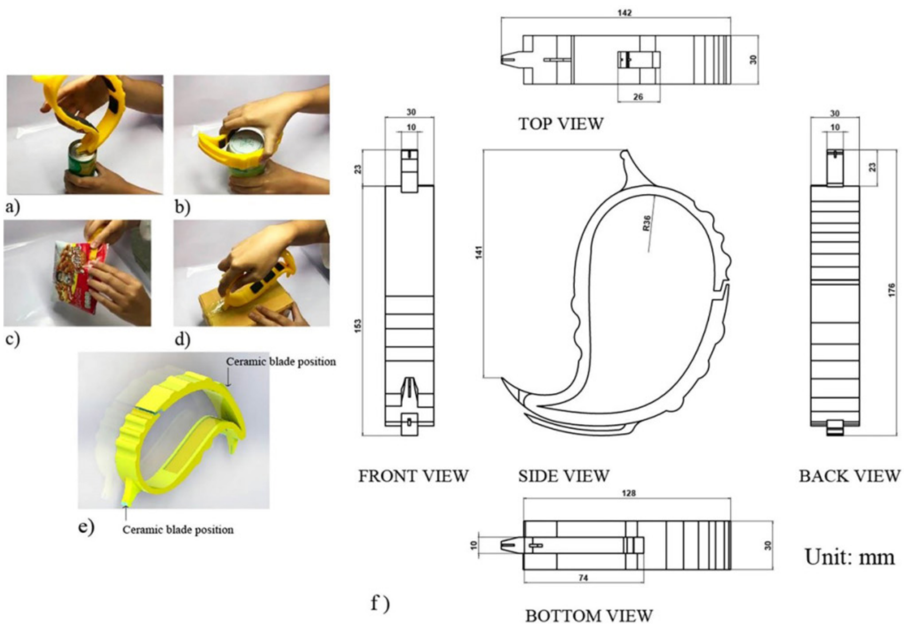
» **Figure 6:** *Grip posture features on 4 packaging with prototype 2*

Figure 6c depicts cutting the flexible packaging for the characterization of opener usage. To remove the seal, the ceramic blade was inserted into the two sides for cutting and slitting on the flat surface of the removable seal. The handy opener was designed with a ceramic blade to easily grip when slitting on the flat surface of packaging. Figure 6d depicts the hand posture when slitting adhesive tape on a corrugated box while gripping the opener. A ceramic blade was inserted on the outside in a comfortable position, allowing consumers to easily grip and increase the cutting force. Figure 6e depicts the ceramic blade positions and a mockup of the second prototype. The structural features of prototype 2 are depicted in Figure 6f.

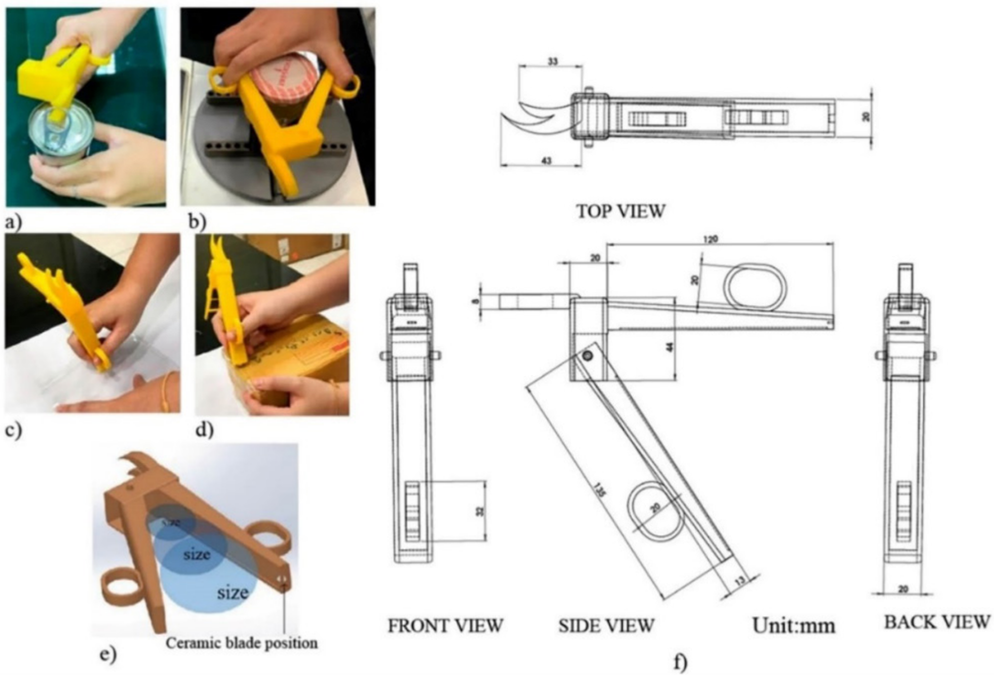
Figure 7 depicts the feature of opener type 3. It was composed of two parts. The first part featured a curved shape for pulling up the easy ring on a can (Figure 7a), while the second part featured a revolved shape of an opener for opening a bottle lug cap or cylindrical screw cap (Figure 7b), cutting flexible packaging (Figure 7c), and cutting the corrugated box (Figure 7d). Figure 7e shows a feature of the third prototype's 3D mockup. For contacting friction when opening a lag



» **Figure 7:** *Grip posture features on 4 packaging with prototype 3*



» **Figure 8:** *Grip posture features on 4 packaging with prototype 4*



» **Figure 9:** *Grip posture features on 4 packaging with prototype 5*

cap, the ceramic blade was placed on the rubber coaster pads with an adhesive liner on the inside surface. Figure 7f depicts the size and shape of prototype 3.

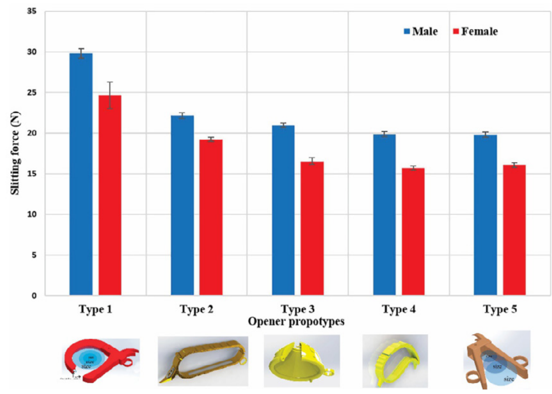
Opener type 4 was designed as the can opener for pulling the easy ring with a J-shaped curve at the end of the product for consumer safety and comfort when opening the packaging, as shown in Figure 8a. The vacuum lug cap's spherical grip was specifically designed to open a variety of sizes. The contacted cap surface was covered with rubber coaster pads with an adhesive liner for the inside surface (Figure 8b). As shown in Figure 8c, the ceramic blade was located inside the extruded part as the opening part for cutting the flexible packaging. The thumb finger can be forced into position and is easy to grip. Figure 8d depicts a simple grip as the lateral posture of the prototype on the corrugated box with the slitting function. Figure 8e shows the 3D Mockup feature and ceramic blade position of the opener type 4. The 2-D engineering drawing shows the shape and dimensions of prototype 4 in Figure 8f.

Figure 9 illustrates the final type of opener developed in this study. There were two parts that interlocked together throughout the four functions of the opening-aided tool for packaging. Figure 9a depicts a consumer's grip posture after pulling the easy ring on a can. The finger rings on both parts can be made to increase grip strength, whereas the rubber coaster pads increase finger friction between the fingers and the container cap outside of the surface (Figure 9b). The ceramic blade for tip grip postures on the opener handle was designed to slit flexible packaging and cut the adhesive tape on the corrugated box, as shown in Figures 9c and Figures 9d, respectively. The prototype 5 was created by combining two elements with the multi-function of opening the packaging (Figure 9e). The drawing of opener prototype 5 is depicted in Figure 9f. The five prototype packages were developed in the study, which included formed transparent plastic sheets and paper board lamination (Figure 10).

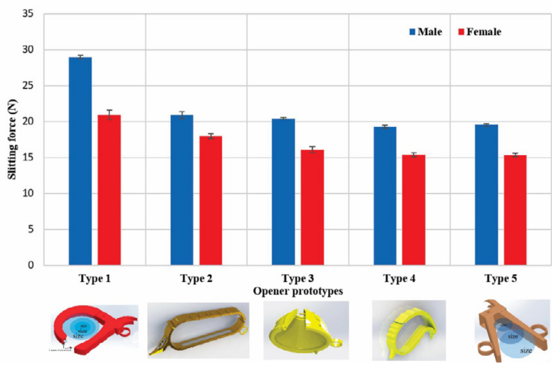
» **Figure 10:** *Packaging design of 5 prototypes*

Evaluation of human force and satisfaction by participants

There were 28 participants in total, with fifteen females (53.5%) and thirteen males (46.5%), ranging in age from 20 to 45 years old, with a mean weight of 61 kg and a mean height of 160 cm. Figures 11 and Figures 12 show that the mean slitting male force was greater than the slitting female force in both the right and left hand of both genders. In comparison to the other prototypes, prototype 1 had the highest mean slitting force. The results indicated that one of the factors influencing the increase in slitting force was the contact surface areas of the hand, fingers, and an assist tool during the test due to the different strengths of both genders. Second, in the gripping style of prototype 1 with pulp grip (Figure 5d), participants produced more slitting force by coordinating their hand and physical finger patterns. The index finger produced a high force value. The function of the thumb finger was directly controlled by the tool's grip position, whereas the middle-ring-little finger group was supported by an originating force contribution from grip manipulation. A similar tendency was obtained by Kamat et al. (2010), Huang et al. (2014) who reported that grip posture patterns, the pressing force, and the position arrangement of each finger affected strength distribution on the surface. For five opener types, males generated higher average slitting force values than females. Females' physical strength is possibly lower, and their hands are smaller than males. This finding is consistent with previous research by Huang et al. (2014), Nilmanee et al. (2018), and Yoxall et al. (2010). As a result, the grip postures of the participants while testing the slitting measurement are depicted in Figure 5d, Figure 6d, Figure 7d, Figure 8d, and Figure 9d.

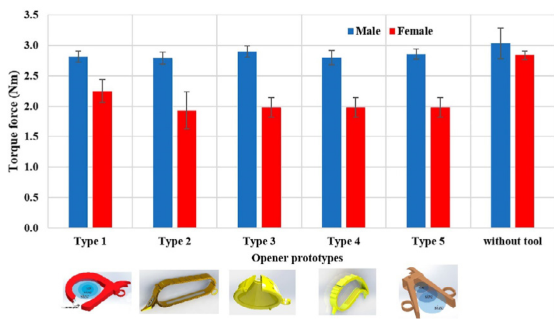


» **Figure 11:** *Mean slitting force of 5 prototypes applied to the plate with the right hand by both genders*



» **Figure 12:** *Mean slitting force of 5 prototypes applied to the plate with the left hand by both genders*

On the basis of force application, the two most common methods of opening grip postures were classified. The first method applied gripping pressure to the prototype in the above direction, as shown in prototype 3 (Figure 7b). On the other hand, human pressure performed in the side direction of the closures can be seen in prototypes 1, 2, 4, and 5 (Figure 5b, Figure 6b, Figure 8b, and Figure 9b). In terms of torque force exertion, all participants were able to open a 60-mm lug cap diameter using only 5 prototypes and their bare hands, as shown in Figure 13. The mean torque force of using the five openers was 2.83±0.05 Nm of males and 2.02±0.13 Nm of females, while without tools, it was 3.04±0.25 Nm of males and 2.84±0.07 Nm of females. When comparing torque force values with and without the tools, the results were slightly different. The previous study found that the torque force effect of the subject's grip posture features differed on the lug closure for the precision grip and the power grip (Yoxall & Rowson, 2014). According to another study by Nilmanee et al. (2018), the force measurement between human and machine speed in the attempt of an opening and peeling test could transmit force difference. These findings indicated that males exerted a greater average torque force than females. Similarly, Bonfim et al. (2016) found that men exerted greater opening torque than women, both with and without gloves. In general, the effectiveness of the opening posture is dependent not only on the physical strength of ordinary packaging under the aided tools of each prototype geometry, but also on the user's hand strength, as in the case of emerging by gender. Furthermore, torque force testing results revealed that friction force against using aided tools is an important factor affecting the absolute implication in opening lug closure with five prototypes. The rubber pads were placed on the prototypes' specific contact areas, increasing the friction force during the opening. Yoxall and Rowson (2018) confirmed these findings, stating that the cap material-skin friction coefficient had a significant effect on the opening torque force. Malea et al. (2020) designed the packaging of innovative toothpaste by considering the mechanism used with the hand and its interaction with the user- friendly.



» **Figure 13:** *Mean torque forces applied by both genders on the jar lug cap of participants for a comfortable hand with the 5 openers and without the opener*

Table 2
Frequency of participant satisfaction score with the prototype of assistant tools (n=28)

Factor	Percentage of satisfaction (%)				
	Type 1	Type 2	Type 3	Type 4	Type 5
Ergonomics and geometry					
1. Comfortable grip posture in hand and finger	91.4	57.1	87.1	69.3	55.7
2. Shape, form, and dimension are suitable for functions for cutting, torqueing, pulling, and slitting	86.4	60.0	87.9	74.3	51.4
Utilities					
3. It can be cut easily	90.0	60.0	87.1	74.3	60.0
4. It can be gripped easily	88.6	60.7	87.1	71.4	61.4
5. Easy to carry during use it	84.3	75.0	68.6	67.9	72.9
Safety					
6. Feel safe and reduce the risk of harm after using	88.6	75.7	89.3	82.1	42.9
7. Good force contribution during use it	87.1	66.4	87.9	72.9	58.6
Commercial and design					
8. Commercial application possibility	82.9	58.3	85.0	72.1	63.6
9. Contemporary trendy and innovation	84.3	62.9	82.1	70.7	52.1
10. Attractive and creative design	83.6	77.1	89.1	80.0	42.1

According to satisfactory evaluation, Table 2 summarizes the percentages of the participant responses using the five opener prototypes after the participants tested opening the packaging. The ergonomics and geometry sufficiency assessment scores of prototypes 1 and 3 were both above 80%. Prototype 1 received higher appreciation scores for user accessibility by cutting, slitting, twisting, and gripping when compared to the other prototypes. More than 80% of participants chose prototypes 1, 3, and 4 based on the results of the safety of use and grip strength tests. Participants were acquainted with prototypes 1, 3, and 4 to imply commercial design.

Conclusion

The functions of user accessibility have sufficiently improved the opener by cutting flexible packaging, slitting off the tape of a corrugated box, twisting the jar lug cap, and pulling the opening ring of a can. The opening enhancement has been combined with four functions into a single tool. The easy-grip, ergonomics, and universal safety features were implemented. On the packages, usability and openability were referred to as finger coordination and grip posture. The design principle of the opener prototypes was created based on form, shape, ratio, dimension, surface contact friction force, and attractiveness. Ultimately, problems with opening packaging can be solved by utilizing the ease of the openers and understanding the user's opening mechanisms. The main concepts of this study were ergonomics and functionalities. The dimension of the packaging openers should be suitable for the hand ratio of both genders to provide further indication of the design concept. These opener analysis results are useful as guidelines for designers and manufacturers to estimate the actual opening postures, product forms, and product conduction before production based on human evaluations of usage, strength, and satisfaction. Function, safety, usability, design, and engineering are important factors to consider when evaluating each product.

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