Table 2 Dimensions and weight of grip object.

No.	Weight (g)	Height (mm)	Width (mm)	Depth (mm)
1	150	50	45	26
2	200	50	60	26
3	250	50	75	26
4	300	100	45	26
5	1200	200	90	26

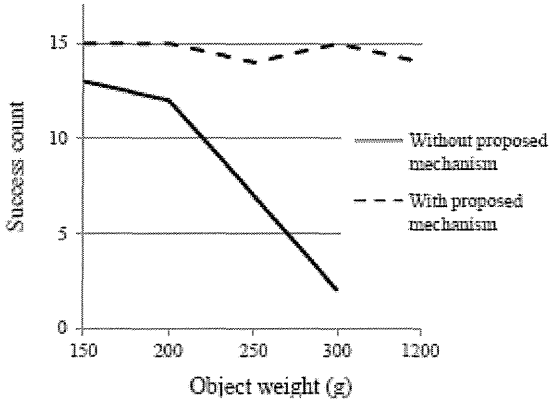

Fig. 9 Number of successful grasps in pick and place task.

allocation mechanism achieved a three-finger grip motion for objects over 1 kg. Because the maximum weight of a grip object without power allocation is 300 g, the grip force was dramatically improved. Therefore, by using the power allocation mechanism, the robot hand simultaneously achieved five-fingered multi-DoF and high gripping force without increasing the size or weight.

Moreover, the success counts with power allocation were greater than those without power allocation for all grip objects. During the tasks, the examinee controlled the myoelectric hand system without difficulty; furthermore, there was no learning effect from practicing prior to the measurement. The new robotic showed improved gripping stability, and the time for each pick and place task decreased. Hence, the power allocation mechanism effectively improved the grip force for a human robotic hand because the DoF constraint was not present when executing a grip force.

5. Conclusions

Herein a five-fingered robotic hand was developed with a power allocation mechanism to improve grip force without a larger and/or heavier mechanism that uses redundant DoFs during precision gripping. The hand motions relative to a human hand and the improvement in grip force were then assessed. The main results are summarized below:

- Relative to a robotic hand without the power allocation mechanism, a robotic hand with the mechanism realizes up to a 63% improvement in the fingertip force, while the total weight only increases by 3.6%. Therefore, the grip force is improved without a significant increase in size or weight.
- A three-fingered gripping motion (thumb, index finger, and middle finger) can grip objects over 1 kg owing to the significant improvement in grip force.
- As demonstrated by the fairly constant success rate for different objects in the pick and place task, the DoF constraint by the power allocation mechanism does not hinder the five-fingered robotic hand.
- The stability of gripping is improved and the time required for each task is reduced.

Therefore, the proposed power allocation mechanism improves the grip force without increasing the size and weight of the robotic hand. The robotic hand with the power allocation mechanism simultaneously achieved the five-fingered multi-DoF and high gripping force.

In the future, we plan to refine the power allocation unit to improve the grip force, make it lighter, and adjust its power allocation for various gripping motions.

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