Attractive force of magnets and magnetic fields
Strength and range of impact by the attractive force of magnets

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Introduction

Most of dental magnetic attachments used in Japan utilize a closed magnetic circuit[1)]. They show excellent attractive force because the magnetic flux density is enhanced within the yoke. On the other hand, other countries utilize some magnetic attachments that utilize open magnetic circuit such as that of a basic magnet[2)]. The attractive force generated in open magnetic circuit attachments is weak compared with that of closed magnetic attachments. Open magnetic circuit attachments are still used in some countries, and may have some advantages.

Objective

The aim of this study was to investigate the influence combining similar and different type of magnets has on attractive force and extent of magnetic fields.

Materials and Methods

Cylindrical neodymium magnets (4 mm in diameter and 2 mm in height, Trusco) and ferrite magnets (5 mm in diameter and 3 mm in height, Trusco) were used in this study. Multiple magnets made of the two different materials (neodymium and ferrite) were combined and arranged in various fashions as shown in Fig 1. Each magnet was fixed using cyanoacrylate adhesive. The keeper (4 mm in diameter and 12 mm in length) made of SUS XM27 stainless steel was used in all setups. The attractive force between the magnets and keeper was measured using a measuring device at a crosshead speed of 2 mm/min. The measuring device used in this study matched ISO 13017 specifications[3,4)] and was connected to a digital force gauge (ZPS, Imada). A typical curve of the attractive force generated is shown in Fig. 2. The attractive force of magnets [C, Fig.2] is acquired by subtracting weight of the mobile part of measuring device and friction during movement [B, Fig. 2] from peak of the curve [A] which is the value of magnetic attachments attractive force, weight of the magnet and movable part of measuring device as well as friction during movement. Point “A” [Fig. 2] signifies the time scenario when the magnet is in contact with keeper just before separation begins.

C＝A-B　(A: initial separation point value, B: weight of device and friction, C: attractive force)

The range of influence by magnetic fields that resulted in an attractive force between keeper and magnet was derived from the attractive force curve and is represented as “S_0”, [Fig 2]. Additionally, the patterns formed by iron powder around the magnets was observed.

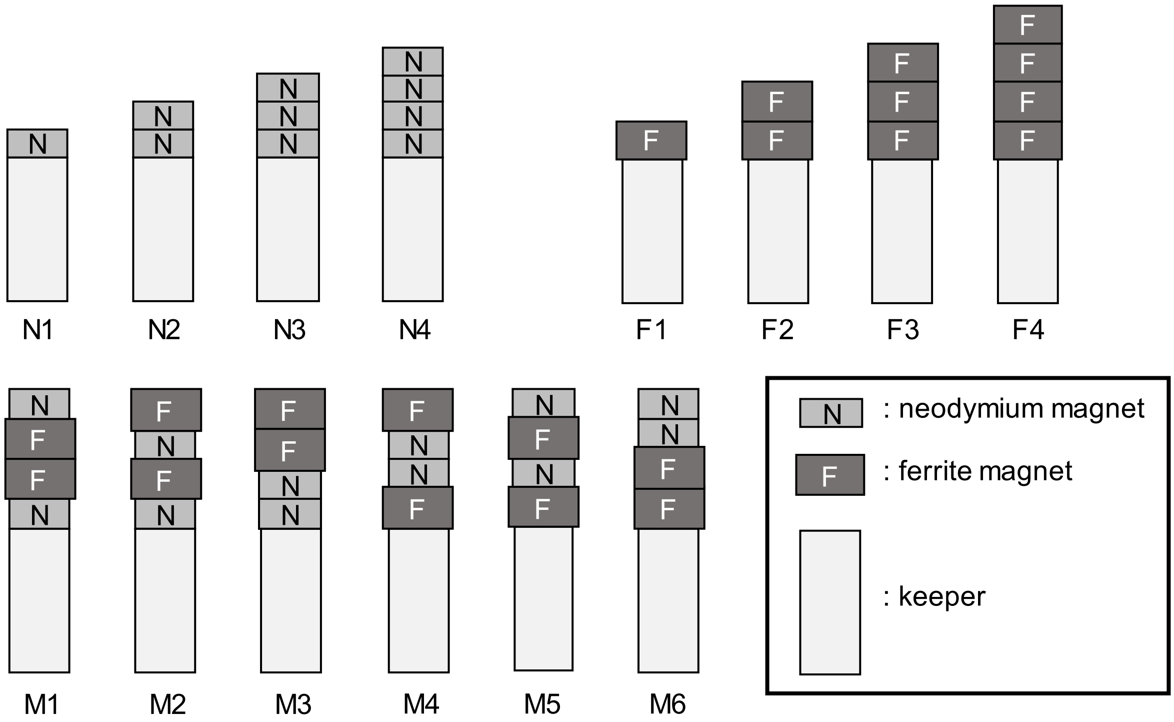


Fig. 1 Combination of magnets

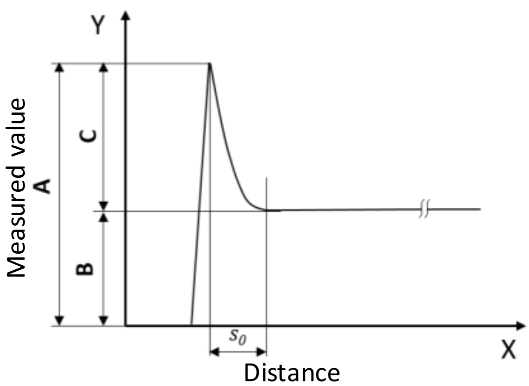


Fig. 2 Attractive force curve

Results

The measured attractive force generated by multiple neodymium magnets and the range of impact by the attractive force is shown in Fig. 3, whereas that of ferrite magnets is shown in Fig. 4. The attractive force value and range of impact by attraction force increased with increase in the number of magnets. The dependency relationship was not linear and the increase diminished with increase in number of magnets.

The attractive force of combined neodymium and ferrite magnets in different arrangements and the range of impact by the attractive forces are shown in Figs. 5 and 6. When a neodymium magnet was in direct contact with the keeper (conditions M1-3), the attractive forces ranged between 3.5 and 4.0 N. The order in a descending manner was M3, M2 and M1 respectively. The range of impact of the attractive force was approximately 6-10 mm with no significant difference across the different setup conditions.

When a ferrite magnet is in contact with the keeper (conditions M4-6), the attractive forces measured were 0.5-0.7 N. The highest was M6, followed by M5, and M4 in descending order. Their extent of magnetic fields was approximately 6-7 mm with no significance difference across the various setup conditions.

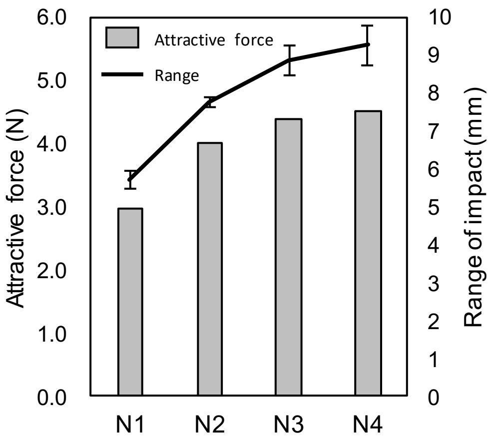


Fig. 3 Attractive force values and range of impact by the magnetic fields of multiple neodymium magnets

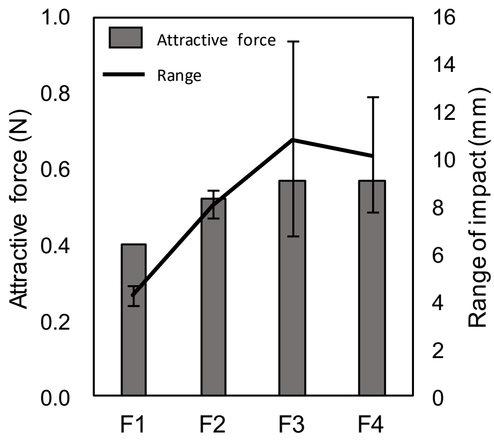


Fig. 4 Attractive force values and range of impact by the magnetic fields of multiple ferrite magnets

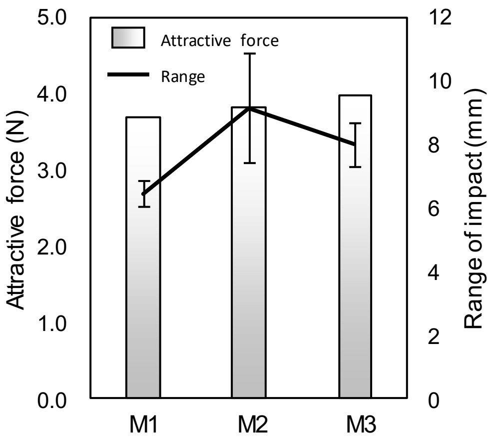


Fig. 5 Attractive force and range of impact of combined neodymium and ferrite magnets (neodymium magnet is in contact with keeper)

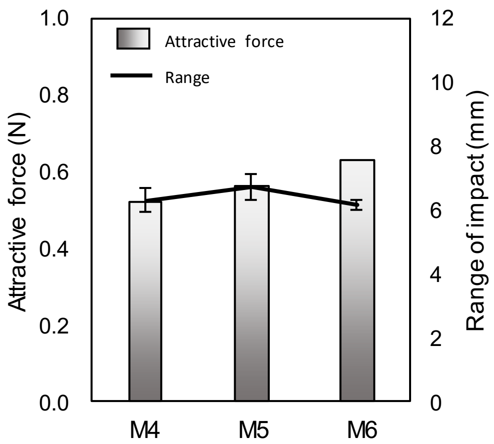


Fig. 6 Attractive force and range of impact of combined neodymium and ferrite magnets (ferrite magnet is in contact with keeper)

Discussion

1. Multiple magnets of similar type

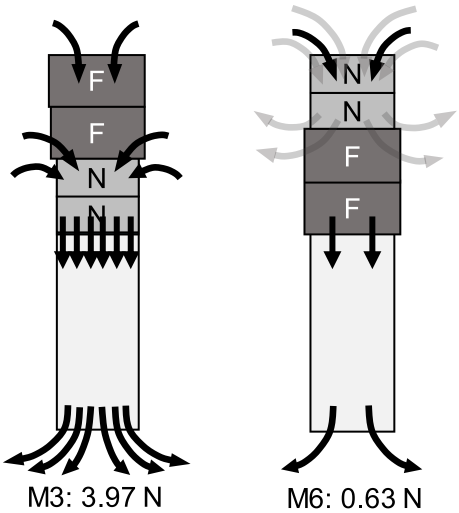
The demagnetizing field is the magnetic field generated by the magnetization in a magnet[1)]. The term demagnetizing field reflects its tendency to act on the magnetization so as to reduce the internal magnetic field, otherwise known as attractive force. The demagnetizing field of a magnet is inversely proportional to the square of the distance between the magnetic poles. The distance between the magnetic poles increases as the number of magnets increases. An increase in the distance between magnetic poles causes a significant change (decrease) in demagnetizing field. Consequently, the attractive force and extent or range of impact by the attractive force increased because demagnetizing field decreased with increase in number of magnets combined. Since the demagnetizing field becomes negligibly small when the distance between the magnetic poles is very large, the attractive force stagnates at a certain value.

2. Combinations of different types of magnets

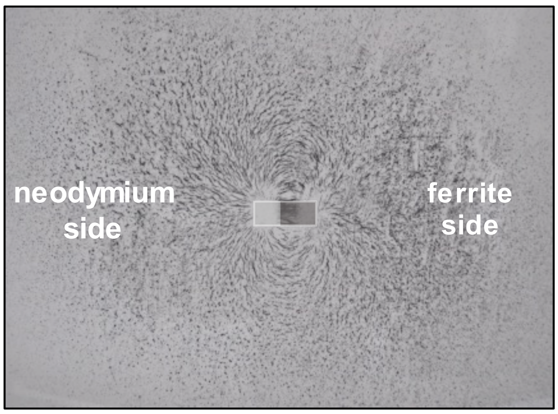
When different type of magnets was combined and the magnet in contact with the keeper was neodymium; the attractive force increased as the number of ferrite magnets between the neodymium ones reduced. The attractive force of a setup involving different types of magnets with a pair of consecutive neodymium magnets in contact with the keeper (M3) was equal to the attractive force of two (similar) neodymium magnets (N2). A setup that involves ferrite magnets sandwiched between a pair of neodymium magnets attenuates the attractive force. The range of impact by the attractive force measured in setups M1-3 also was equal to that of N2.

When the magnet in contact with the keeper was ferrite (M4-6), it was expected that neodymium magnets would enhance the attractive force of ferrite magnets. However, the obtained results differed from the expectation. The amount of magnetic flux which can pass through a ferrite magnet is much less than that of a neodymium magnet. A ferrite magnet placed adjacent to the keeper would therefore interfere with the flow of magnetic flux from neodymium magnet to the keeper. The attractive force of mixed type of magnets whereby two consecutive ferrite magnets were in contact with keeper (M6) was relatively higher than that of neodymium sandwiched between ferrite or one ferrite adjacent to keeper M4-5. Possibly, a part of the magnetic flux from the neodymium magnet leaked through the sides of the cylindrical keeper. Although the attractive force of M4-6 was equal to or higher than that of F2-4, the range of impact by the attractive force for M4-6 setups was smaller than that of F2-4. It is desirable of magnets for intraoral applications to have a small range of impact by the magnetic fields[1]. This study demonstrated that it is possible to control the extent of magnetic fields without changing attractive force through combination of different kinds of magnets.

Setups denoted as M3 and M6 constitute of two consecutive neodymium and ferrite magnets. Excluding the keeper, M3 is the reverse setup of M6 whereas M2 is the reverse of M5. However, the attractive force when neodymium contacts keeper (M2 or M3) was higher than that of ferrite in contacts with keeper (M5 or M6). Even if the magnetic composition was the same, the force of the magnet structure changed based on the side which contacts with a keeper. This is because the amount of the magnetic flux which can pass through a ferrite and neodymium material differs, as shown in Fig. 7. From these results, we may be able to develop a magnetic application with which the attractive force differs depending on the side which contacts with.



Influence of the magnetic pole in contact with keeper on attractive force value



Pattern of magnetic fields (M3, M6)

Fig. 7 Features of combined magnets of different types

Conclusion

Similar or different type of magnets combined in various fashions showed unique features with regard to the strength value of attractive force and the range of impact. This study suggests that the attractive force value and range of impact by the magnetic fields can be controlled through combination of different kinds of magnets.

Acknowledgments

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References

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