A surveillance study of the demand of titanium and titanium alloys in Japan

Tomotaro NIHEI¹, Katsura OHASHI¹, Masayuki HATTORI² and Satoshi IMAZATO³

¹ Division of Clinical Biomaterials, Department of Oral Science, Graduate School of Dentistry, Kanagawa Dental University, 82 Inaoka-cho, Yokosuka, Kanagawa 238-8580, Japan

² Department of Dental Materials Science, Tokyo Dental College, 2-9-8 Kanda-Misaki-cho, Chiyoda-ku, Tokyo 101-0061, Japan

³ Department of Biomaterials Science, Osaka University Graduate School of Dentistry, 1-8 Yamadaoka, Suita, Osaka 565-0871, Japan

Corresponding author, Tomotaro NIHEI; E-mail: nihei@kdu.ac.jp

The demand for titanium and titanium alloys in dentistry is high. A surveillance survey regarding the clinical and laboratory uses of titanium/titanium alloys in Japan was conducted in this study. The alloys used for casting demonstrated a decreasing tendency in quantity, whereas the use of non-casting titanium alloys increase in the market. This increasing trend is reflected the popularity of CAD/CAM devices. In Japan, the processing technologies of titanium alloys have been improved; therefore, the application of titanium and titanium alloys to dental procedures covered by the insurance is clearly worth considering.

Keywords: Dental materials, Titanium, Titanium alloys, Demand and supply, Research study

INTRODUCTION

Titanium and titanium alloys are highly biocompatible materials used in endosseous dental implants and restorative or denture materials. They are commonly used in the field of dentistry. However the costs of high noble metals including palladium are rising continuously. The overburdening of the Social Insurance Medical Fee Payment Fund owing to frequent use of the gold-silver-palladium alloy is a cause of concern in Japan; hence, it is important to find an alternative alloy.

Based on these conditions, we conducted a surveillance survey on the clinical and laboratory uses of titanium/titanium alloys.

The usability of titanium and titanium alloys

Titanium is the tenth most abundant elements on earth. It is a relatively light metal with a density of 4.54 g/cm³. Additionally, it forms a stable oxidized surface resistant to corrosion *in vivo* thereby demonstrating high tissue affinity and biocompatibility as a biomaterial¹⁻³⁾. However, it is necessary to form alloys of Ti-6Al-4V or Ti-6Al-7Nb in order to achieve high physical properties⁴⁻⁶⁾. In addition, although the wear resistance of titanium and titanium alloys is not as high as that of a cobalt-chromium alloy, it is higher than those of noble metals^{7,8)}. One study demonstrated the superior wear resistance of a titanium alloy during wear testing in simulating chewing cycles⁹⁾ and indicating its clinical effectiveness.

Consumption of titanium and titanium alloys

The demand for aircraft production accounts for approximately a half of the titanium in the metal industry; nonetheless its application in field of medicine is increased (domestic shipments of titanium for use in 1998 was 0.4%) in Japan. In 2014, the shipment volume of the material was 14,000 tons. The greatest obstacle in the popularization of titanium is its high cost. Thus, it

is essential to reduce the cost of titanium production for further use in the fields of medicine and dentistry.

According to The Statistical Survey on Trends in Pharmaceutical Production (2015)¹⁰⁾, the annual production and shipment costs (Fig. 1) of dental titanium casting and non-casting alloys were 5,086,000 and 43,881,000 yen respectively; the costs of titanium alloys for implants were 18,424,983,000 yen. Non-casting titanium alloys include titanium blanks for cutting and orthodontic wires, while those for dental implants include fixtures, abutments and screws.

In Japan, the shipment volumes are correlated with the cost of the casting titanium alloys to some extent, and it is relatively easy to grasp the trend of the market. Furthermore, when casting alloys shows a decreasing trend in the quantity their unit values is also lowered. On the other hand, the used of non-casting titanium alloys increase in the market resulting in an increase the price relative to the shipment volumes. This increasing tendency reflects the popularity of CAD/CAM (computer-aided design and computer-aided manufacturing) devices. Therefore, it is predicted that an increase in the number of milling machines equipped in dental laboratories will be lower the unit values of the material.

Current state of laboratory processes of titanium and titanium alloys

Titanium has been considered as a promising dental material for years. However, characteristics such as the melting point, oxidation and density, leading to the development of a new casting system delayed its actual application in the dental field. The melting point of titanium is approximately 1,668°C, and is extremely high relative to those of gold (about 950°C) and cobalt-chromium (about 1,300°C) alloys. In addition, since titanium tends to undergo oxidation at high temperatures and has a low density, a new casting system to obtain

Fig. 1 Shipment volumes and values of titanium materials for dental use (2011-2015).
Source) Statistical Survey on Trends in Pharmaceutical Production

Fig. 2 Itemized shipment values of medical devices (2015).
Source) Statistical Survey on Trends in Pharmaceutical Production

sufficient casting pressure is required. Therefore, the development and modification of titanium casting machines such as a casting machine with a vacuum unit and an argon-arc melting and a vacuum/pressure casting system, have been attempted continuously^{11,12)}.

In Japan, the domestic shipments of casting machines and related devices for dental laboratories such as high-frequency casting machines, casting machines with a heating furnace, and casting machines with an external heating system cost 174,337,000, 16,975,000 and 48,712,000 yen, respectively, according to the data (2015) on production, import, shipment, and inventory value of itemized medical devices¹⁰⁾ (Fig. 2). On the other hand, the costs of CAD/CAM devices for dental laboratories was 4,253,000,000 yen.

Fabrication of processed titanium prosthodontic devices using electric discharging has been reported¹³⁾. Prostheses made from zirconium and titanium using dental CAD/CAM systems have been applied clinically¹⁴⁾. Processing technologies of CAD/CAM materials are rapidly improving, and 3D printing appears to show promise relative to milling of titanium. It is essential to

develop materials and specific production technologies that can reduce the manufacturing costs and the cost of the titanium itself as with the approach of the general industry¹⁵⁾.

Data about the number of dental laboratories equipped with machines for processing titanium remain unclear. According to the status survey report of dental technicians (2015)¹⁶⁾, 60% of cooperative laboratories and 31% of individual laboratories fabricate dental implant prostheses using titanium. CAD/CAM prostheses are fabricated by 55 and 20% of the cooperative and individual laboratories, respectively. Large-sized laboratories are equipped with titanium processing machines, but the number of individual laboratories that possess them is small in Japan.

CONCLUSION

The insurance system has approved the use of resin blocks for CAD/CAM restorations of molars in Japan. Titanium or titanium alloys are viable options for molar restorations that are not suitable for resin blocks or

molar bridges. Using an appropriate casting machine and mold material, titanium or titanium alloys can provide a comparable level of fitting accuracy with a gold-silver palladium alloy¹⁷⁾. The selection of an alternative metal is important owing to the surging cost of palladium. The processing technologies of titanium alloys are in place; therefore, the application of titanium and titanium alloys to dental procedures covered by the insurance is clearly worth considering.

ACKNOWLEDGMENTS

Supported in part by a grant from Japanese Dental Science Federation, JDSF-DSP1-2018-107-1.

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