Journal of Dental Sciences (2017) 12, 226–232

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com

Journal of Dental Sciences

ORIGINAL ARTICLE

The possibility of recasting of pure titanium

Pei-Ling Lai [a], Wen-Cheng Chen [b], Jen-Chyan Wang [c,d*], Po-Sung Fu [e], Chih-Chiang Lin [c], Chun-Cheng Hung [a,c,d*]

[a] *Dental Medical Devices and Materials Research Center, College of Dental Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan*
[b] *Advanced Medical Devices and Composites Laboratory, Department of Fiber and Composite Materials, College of Engineering, Feng Chia University, Taichung, Taiwan*
[c] *School of Dentistry, College of Dental Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan*
[d] *Department of Prosthodontics, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*
[e] *Department of Family Dentistry, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*

Received 17 February 2017; Final revision received 20 February 2017
Available online 1 April 2017

KEYWORDS
magnesia-modified investment;
pure titanium;
recasting

Abstract *Background/purpose:* Pure titanium (Ti) has many advantages, such as high corrosion resistance and excellent biocompatibility. The mechanical properties of pure Ti are like those of type IV gold alloys. Furthermore, gold alloys can be successfully recast in dental clinics. The aim of this study was to investigate the possibility of recasting pure Ti.
Materials and methods: Magnesium oxide (MgO)-based investment that contained a 5 wt. % zirconium dioxide (ZrO_2) additive was used. An argon-casting machine (Castmatic-S, Iwatani) was used to recast pure Ti. The first generation and second generation pure Ti (50 wt. % new Ti + 50 wt. % surplus Ti) were used. Five specimens were fabricated and tested. The data were evaluated using two-sample t-test analysis ($P < 0.05$).
Results: The experimental results showed that recasting the Ti did not decrease the marginal accuracy, average surface roughness, Vickers hardness value of the superficial surface, and the thickness of the reaction layer.
Conclusion: This study clearly showed Ti could be recast when a 5 wt. % ZrO_2 additive MgO-based investment was used. This modified investment has the potential for use in clinical applications.

* Corresponding authors. School of Dentistry, College of Dental Medicine, Kaohsiung Medical University, Kaohsiung Medical University Hospital, Number 100 Tzyou First Road, Kaohsiung City 807, Taiwan.
E-mail addresses: jechwz@kmu.edu.tw (J.-C. Wang), yuchali@ms21.hinet.net (C.-C. Hung).

http://dx.doi.org/10.1016/j.jds.2017.02.004

Introduction

For centuries, alloys with a high content of noble metals including gold, palladium, and platinum have been used to fabricate fixed prostheses because of the resulting high quality, performance, and ability to meet safety standards. However, the escalating cost of gold has contributed to the widespread use of base metal alloys, such as Co—Cr, Ni—Cr, Ti, and Ti-alloy. Among these materials, pure titanium (Ti) has adequate mechanical properties, high corrosion resistance, and excellent biocompatibility.[1] Therefore, pure Ti has been extensively used in medical and dental applications, such as implants.

In implant prostheses, late failure has been linked to infections, incorrect occlusal loadings, and material incompatibilities. Popular dental implant components are conventionally made of pure Ti only. However, the suprastructures can be made of several alloys, such as Au—Pd, Ni—Cr, Co—Cr, and Pd—Ag. The use of a combination of different types of metals or alloys in the oral cavity can lead to galvanic corrosion and can subsequently induce implant failure. Therefore, the use of a single restorative and biocompatible material, pure Ti, is recommended to avoid galvanic corrosion.[2] Precise dental restoration requires a casting system to replicate complex shapes with high fidelity. In addition, the marginal accuracy of dental prostheses is usually better with a traditional casting technique than with computer-aided design and computer-aided manufacturing fabrication.[3] However, pure Ti can easily react with oxygen at high casting temperatures or a reaction could occur during the casting process. Ti ingots may accumulate dental plaque, which leads to poor marginal accuracy in the restoration and results in secondary caries. Therefore, the role of pure Ti in dental prostheses has increased in importance, and several studies have shown that the accuracy and quality of pure Ti castings have been improved with the use of new casting machines and mold materials.[4—11]

Commercially available silica investments can easily be reacted with Ti to produce a very thick reaction layer for a Ti casting. Therefore, alumina (Al_2O_3), magnesia (MgO), calcia (CaO), zirconia(ZrO_2), and yttria (Y_2O_3) have recently and frequently been used as an oxide inhibitor in Ti casting.[4—11] One application of these compounds is a magnesium oxide (MgO)-based investment, which can significantly reduce the interfacial reactivity and is easy to manipulate.[1,4] However, the disadvantage of MgO-based investments is the low thermal expansion rate that might not correspond to the thermal properties of Ti ingots, making it difficult to obtain a high-precision Ti casting due to the marginal discrepancy. Hung et al[7] added 5.0 wt. % zirconia to a MgO-based investment; this modification was able to increase the thermal expansion and solve the problem of marginal discrepancy. In addition, the interfacial reactivity of the castings made from the zirconia/MgO-based investment was less than that of the MgO-based investment even at high casting temperatures.

In dental laboratories, surplus alloys from the initial casting are commonly reused for economic reasons and to avoid the exploitation of natural resources. Several investigations have shown the effect of recasting within different dental alloys. For example, recasting a low-Au alloy obviously affected the basic properties, such as the yield strength, elemental distribution, hardness, and percentage elongation.[12] Furthermore, the zone of Ag_2O oxidation could be increased by recasting a Pd-Ag porcelain alloy; this recasting led to increased hardness and corrodibility.[13,14] In contrast, recasting Ni-Cr alloy did not lead to remarkable degenerative changes in the physical properties, microstructure, and clinical characteristics.[15] Recasting different alloys through investments that had different components led to varied properties. Therefore, the effect of the recasting pure Ti using a 5.0 wt. % zirconia/MgO-based investment must still be investigated. Consequently, whether Ti recastings can be produced with high quality and high precision is unclear. This investigation evaluates a Ti recasting that uses a new investment mold and characterizes the effect of the Ti recasting on the marginal precision.

Materials and methods

Preparation of investment

The MgO-based investment Selevest CB (Selec Co., Osaka, Japan) was used as the control group. The investment was further modified by the addition of 5.0 wt. % zirconia (ZrO_2, Hayashi Pure Chemical Industries, Japan), and the modified investment was used as the experimental group. The powders for the modified investment were blended in a mechanical vacuum mixer (Whip Mix, Louisville, Kentucky, USA) before mixing with water. The recommended liquid/powder (L/P) ratio for both groups was 20 mL/100 g.

Preparation of castings

The mesial-occlusal-distal (MOD) metal die cast molding was used to assess the casting inlay accuracy. This method is schematically shown in Figure 1. In brief, a wax pattern (8.0 mm in diameter, 7.0 mm in height, and 2.0 mm in thickness) was placed on the metal die. The distance separating the metal die shoulder from the margin of the wax pattern was measured at four fixed points for each specimen, set as dx, and calculated. Five specimens were fabricated and tested for each group. The specimens were invested in casting rings (36 mm in diameter and 46 mm in height) with a layer of ring liner (35 mm in diameter and 2 mm in thickness, J. Morita Co., Kyoto, Japan) and a sprue (3 mm in diameter and 25 mm in length). The invested molds were burned out in a programmed electric furnace at a rate of 6°C/min to 850°C and were then kept at this temperature for 1 hour. After 1 hour of heat soaking, the invested molds were bench cooled to 800°C.

An automatic argon-arc vacuum-pressure casting machine (Castmatic-S, Iwatani Co., Osaka, Japan) and commercial pure Ti ingots (JIS Grade 2, Ohara Co., Osaka, Japan; about 7 g, >99.5%) were used in this research. In the first generation, all new Ti ingots were placed on the copper crucible, and a tungsten electrode was placed 5 mm above the ingot center. The argon pressure was 1.8 kgf/cm^2 with 250 A of current. After casting, the molds were bench