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Tanta Dental Journal 12 (2015) 119–123

www.elsevier.com/locate/tdj

Marginal accuracy in casting titanium fixed partial dentures

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Received 24 July 2014; accepted 27 March 2015
Available online 8 May 2015

Abstract

Purpose: This study evaluated marginal accuracy of cast titanium using three-unit fixed partial denture (FPD).
Materials & methods: A two-abutment stainless-steel die was used to duplicate a set made of stone die and epoxy master die. The FPD wax pattern made on stone die was invested in mold. Commercially pure (CP) Ti was cast using centrifugal casting unit in magnesia mold. As controls, nickel–chromium (Ni–Cr) and type IV gold alloys were cast centrifugally into phosphate and cristobalite molds, respectively. Overall burnout schedules followed manufacturers' instructions. Each casting was luted to epoxy die under 2 kgf static load. The luted assembly was cut longitudinally at center of the casting. The clearance between die and casting was measured at different measurement locations along cervical shoulder, and data (μm) for exterior or interior shoulders (n = 10 bridges; 20 shoulders) were averaged in terms of vertical gap (VG) and horizontal discrepancy (HD), then were statistically analyzed by ANOVA/Tukey test ($P < 0.05$).
Results: The VG and HD values of titanium specimens showed less marginal accuracy compared to the others at all measurement locations of exterior shoulders. However, there was no statistical difference ($P > 0.05$) among the cast metals at interior shoulder except at I–J location (Horizontal Discrepancy) in which all horizontal discrepancy values were negative.
Conclusions: Using a magnesia investment, marginal accuracy of cast titanium was evident to be less than that of conventional alloys of simulated FPD restoration. The correlation between thermal expansion and titanium bridge accuracy is still high.

Keywords: Margins; Titanium; Fixed prosthesis; Thermal expansion

1. Introduction

Gold alloys have been successfully used in the construction of dental fixed prostheses for many years. However, gold alloys still have some disadvantages such as their high cost, questions about their role in the source of contact allergic reactions [1,2], in vitro evidences of cytotoxicity caused by their released copper and zinc elements [3]. Therefore, less expensive alternatives have been developed using both noble and base metals. Unfortunately, some base metal alloys have the disadvantage of health risks related to elements such as nickel and beryllium [3]. Commercially pure titanium (CP Ti) has been used as a replacement for these conventional alloys. CP Ti provides excellent biocompatibility, good corrosion resistance at room temperature, radiographic radiopacity, high ductility, low thermal conductivity, low density and high mechanical resistance [4–7]. In theory, the light weight of

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Peer review under the responsibility of the Faculty of Dentistry, Tanta University.

http://dx.doi.org/10.1016/j.tdj.2015.03.002
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Table 1
The materials of tested castings and their corresponding investments.

Material	Manufacturer	Product	Composition (wt%)	Investment
CP Ti grade II	Titanium Ind., Rockaway, NJ	ASTM-II	100 Ti	Magnesia (Selevest CB, Selec, Osaka, Japan)
Type IV	Tokuriki Honten, Tokyo, Japan	GP Type IV	68 Au, 12.5 Cu, 10 Ag, 4.5 Pt, 3 Pd	Cristobalite (Whip Mix, Loisville, KY)
Ni–Cr	Talladium, Valencia, CA	Talladium V	60–76 Ni, 12–21 Cu, 4–14 Mo, 4–6 Ti <2 Be	Phosphate (Talladium, Valencia, CA

titanium and its high strength-to-weight ratio allow the design of more functional and comfortable prosthodontic restorations [8]. CP Ti is frequently used for dental implants and more recently, for crowns, bridges. However, pure titanium casting is problematic because of its high melting point and increased sensitivity at high temperatures to surrounding conditions than conventional dental alloys. Molten titanium has high affinity for gas elements such as oxygen and nitrogen, and high reactivity with silica investment materials which caused a reactive layer (alpha-case) on the surface with resultant inadequate titanium castability [9–11]. Therefore, specially formulated investment materials containing components with low standard free energy of oxides such as alumina, magnesia, calcia have been developed. Substituting a magnesia-based investment for one that is silica-based has significantly reduced titanium interfacial reactivity [12,13].

The minimization of fixed prosthodontic restoration marginal gap is an important aim in the field of prosthodontics. The essence of concern is the space existing between the tooth preparation and the restoration margins where both meet the oral environment. Highermarginal accuracy (smaller marginal gaps) leads to less gingival irritation [14], less cement washout [15] and hence improving the clinical outcome and longevity of the restoration. Information on the marginal fit of titanium bridges is limited, and the results of titanium crown studies are contradictory. Bergman et al. [16] reported that the marginal fit of titanium crowns was satisfactory. Blackman et al. [17] found that the dimensional changes in cast titanium removable partial denture frameworks were similar to those found with nickel–chromium alloys. Then, Blackman et al. [4] pointed out that pure titanium copings could be cast, fitted, and cemented to their dies with acceptable fitting accuracy. Compared to other alloys, titanium marginal fit was reported to be inferior to that of silver–palladium but superior to that of nickel–chromium crowns [12]. However, other studies showed that marginal accuracy of gold alloy is significantly better than that of titanium [18,19]. Also, Leong et al. found that marginal openings of cast titanium crowns and machine-milled titanium crowns were not significantly different from each other [19]. It has been stated that the marginal fit of single titanium crowns is better than titanium three-unit FPD [20]. It is important to note that all previous studies dealt with marginal accuracy of CP Ti inlays or crowns to compare them to other alloys. Accordingly, the aim of the present study was to evaluate and compare the marginal accuracy of three-unit FPDs made of cast CP Ti and two other commonly used conventional alloys (Type IV gold alloys: commonly used in developed countries such as United States, Europe and Japan; and Nickel–chromium alloy: commonly used in developing countries such as Middle East and South America).

2. Materials and methods

2.1. Preparation of the specimens

The materials tested are listed in Table 1. Sets of epoxy[1] master dies and stone[2] dies were prepared by duplicating a two-abutment stainless-steel die (Fig. 1) with shoulder margins using polyvinyl siloxane impression material.[3] Then, fixed partial denture (FPD) wax patterns were made on the stone dies using a custom-made brass mold; the patterns were left on the dies for 1 day to release residual stress. After refining the margins around the shoulders, each sprued wax pattern was invested in a mold ring with the investment materials listed in Table 1. The molds were burned out following the schedules recommended by the manufacturers. The mold temperatures before casting were 200 °C for magnesia investment, 650 °C for

[1] Epoxide, Buehler, Northridge, CA.
[2] Silky-Rock, Whip Mix Corp., Louisville, KY.
[3] Extrude, Kerr, Orange, CA.