Fracture strengths of newly designed metal-based complete maxillary dentures made from a cobalt-chromium alloy with high elastic modulus

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Purpose: The purpose of the present study was to evaluate the fracture strengths of a metal-based complete maxillary denture with a metal framework (that did not extend to the residual ridge crest), which was made from a cobalt-chromium alloy with high elastic modulus.
Materials and Methods: Sample newly designed metal frameworks of metal-based complete maxillary dentures were cast in a cobalt-chromium alloy with high elastic modulus. The maximum fracture strengths of dentures were measured using a universal testing machine. The mean value was statistically compared to that of a conventional cobalt-chromium alloy measured in a previous study.
Results: The fracture strength of the metal-based complete maxillary dentures made from a cobalt-chromium alloy with high elastic modulus was significantly higher than that of the conventional cobalt-chromium alloy.
Conclusion: The results of this in vitro study indicate that a cobalt-chromium alloy with high elastic modulus provides superior fracture strength for metal-based complete maxillary dentures with a newly designed metal framework. **(Int Chin J Dent 2005; 5: 61-64.)**

Key Words: cobalt-chromium alloy, elastic modulus, fracture strength, metal-based complete maxillary denture, metal framework.

Introduction

The metal-based framework for a complete maxillary denture commonly covers the palate and residual ridges, with the borders made of acrylic resin.[1] In a previous study,[2] a newly designed metal framework for metal-based complete maxillary dentures that did not extend to the residual ridge crest was devised in order to facilitate arranging the artificial teeth when there is not enough space between the upper residual ridge crest and the antagonist. The previous study showed that the fracture strength of the metal-based complete maxillary denture with the newly designed metal framework made from a conventional cobalt-chromium alloy was approximately two times greater than that of the resin-based denture, but was lower than the strength of a conventionally designed metal-based denture.

It was hypothesized that the increased mechanical properties of the metal framework material should improve the fracture strength of the metal-based denture. Therefore, the purpose of the present study was to attempt to achieve better fracture strengths of a metal-based complete maxillary denture with a newly designed metal framework using a cobalt-chromium alloy with high elastic modulus, which has superior mechanical properties compared with a conventional cobalt-chromium alloy.

Materials and Methods

The cobalt-chromium alloys used in this study and the previous study,[2] their trade names, manufacturers, batch numbers, chemical compositions, and technical data are listed in Table 1. Stone casts (Fujirock, GC Corp.,

Tokyo, Japan) and also duplicate and refractory casts (Rema Exact, Dentaurum Inc., Newtown, PA, USA) of the maxillary edentulous model (G1-402, Nissin Dental Products Inc., Kyoto, Japan) were made. The metal framework was constructed with the new design[2] cast from a cobalt-chromium alloy with high elastic modulus using the refractory casts. The cast metal frameworks were airborne-particle abraded with 50 μm grain-sized aluminum oxide particles using a grit blaster (Micro Blaster MB102, Comco Inc., Burbank, CA, USA) and then electrochemically polished. A heat-polymerized poly(methyl methacrylate) (Vertex Rapid Simplified, Vertex-Dental B.V., Oldenbarneveltlaan, Netherlands) was applied to the denture base material on the stone casts. The thickness of the denture bases was adjusted to 2.5 mm according to the method described previously.[2] All the dentures were stored in 37°C distilled water for 50 hours before testing.

Table 1. Cobalt-chromium alloys used in this study and the reference 2, their chemical composition (mass %), and technical data.*

	Co-Cr alloy with high elastic modulus	Conventional Co-Cr alloy
Trade name	Remanium GM800	Remanium GM380
Manufacturer	Dentaurum Inc., Newtown, PA, USA	Dentaurum Inc.
Batch number	340301	9930
Composition	Co 63.3%, Cr 30.0%, Mo 5.0%, Si 1.0%, others 0.7%	Co 64.6%, Cr 29.0%, Mo 4.5%, others 1.9%
Yield strength $R_{p\,0.2}$	720 MPa	640 MPa
Tensile strength R_m	960 MPa	900 MPa
Hardness (HV 10)	370	360
Elongation range A_5	6.0%	6.5%
Modulus of elasticity E	230 GPa	220 GPa

*The data were obtained from the literature on manufacturer's product information.

The maximum fracture strengths were measured using a universal testing machine (Autograph AGS-J, Shimadzu Corp., Kyoto, Japan) at a crosshead speed of 5.0 mm/minute with an 11.5 mm ball attachment. The mean fracture strength of 10 dentures was statistically compared with that of the identically designed dentures made with a conventional cobalt-chromium alloy obtained in the previous study[2] using the Student t-test ($p<0.01$). The types of fracture were categorized after testing.

Results

The comparison between the present and previous results revealed that the fracture strength of the metal-based complete maxillary dentures cast in a cobalt-chromium alloy with high elastic modulus was significantly higher than that cast in a conventional alloy[2] (Table 2). The types of specimen failure after testing are presented in Table 3.

Table 2. Fracture strengths for each alloy.

Group	Fracture strength (kN)	Mean	SD
Co-Cr alloy with high elastic modulus		2.01	0.50
Conventional Co-Cr alloy		1.49	0.24

SD, standard deviation. The data shown for the conventional Co-Cr alloy were obtained from the reference 2.

Table 3. Type of fracture.

Type of fracture	Co-Cr alloy with high elastic modulus	Conventional Co-Cr alloy
Fracture or deformation of metal framework	20%	60%
Fracture at metal framework outline	40%	40%
Fracture of base resin	60%	20%

The data shown for the conventional Co-Cr alloy were obtained from the reference 2.

Discussion

The fracture strengths of the metal-based complete maxillary dentures made of a conventional cobalt-chromium alloy[2] were superior to the maximal bite forces of the complete denture wearers.[3,4] This result suggested that the application of this new metal framework is acceptable. However, when a conventional cobalt-chromium alloy was used, the fracture strength of the new metal framework was significantly lower than that of the conventional design,[2] but the fracture strength of the new design should be at least the same as the conventional one. Furthermore, even if the yield strength or the proportional limit is within the acceptable range for the denture, repetitive loads may finally lead to denture fracture. Therefore, a cobalt-chromium alloy with high elastic modulus was used to obtain higher fracture strength for the complete maxillary dentures.

The results of this study indicated that the fracture strength of metal-based complete maxillary dentures made of a cobalt-chromium alloy with high elastic modulus was significantly higher than that of the dentures made of a conventional alloy. This finding is probably due to the superior mechanical properties, especially the higher elastic modulus of the alloy (Table 1). The fracture strength of a cobalt-chromium alloy with high elastic modulus may be satisfactory for metal-based complete maxillary dentures because additional evaluation revealed no significant differences between the present experimental framework and the metal framework using a conventional alloy (2.01 kN)[2] ($p>0.01$). Cobalt-chromium alloys with a much higher elastic modulus are used to make clasps, which result in very rigid frameworks, and have a high fatigue fracture resistance.[5] This property is one of the advantages of using a cobalt-chromium alloy with high elastic modulus.

Fracture at the metal framework outline without fracture of the base resin occurred in 40% of the specimens. Such a fracture indicated that the stress concentration against the compressive load in the center of the plate tended to occur along this line. The frequency of fracture or deformation of the metal frameworks decreased, and the fracture of the base resin increased using a cobalt-chromium alloy with high elastic modulus compared to conventional alloy. This finding indicates that it is more difficult for frameworks made with a cobalt-chromium alloy with high elastic modulus to deform. Further in vitro studies are necessary to evaluate the effect of the bonding system on the fracture strength of the metal-based denture.[6]

Conclusion

The cobalt-chromium alloy with high elastic modulus provides superior fracture strength of metal-based complete maxillary dentures with a newly designed metal framework.

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