Fracture strength of metal-based complete maxillary dentures with a newly designed metal framework

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Purpose: The purpose of the present study was to evaluate the fracture strength of a metal-based complete maxillary denture with a newly designed metal framework that did not extend to the residual ridge crest.
Materials and Methods: Metal-based complete maxillary dentures with a conventionally designed metal framework (group A) and those with a newly designed metal framework (group B) were cast in cobalt-chromium alloy. Resin-based complete maxillary dentures (group C) were also fabricated as a control. The maximum fracture strengths were measured using a universal testing machine at a crosshead speed of 5.0 mm/minute. The differences in the mean values were compared by means of one-way ANOVA and the Student-Newman-Keuls post-hoc comparison test.
Results: The fracture strength of group A (2.01 kN) was significantly higher than that of group B (1.49 kN) ($p<0.05$). The fracture strength of group B was significantly higher than that of group C (0.79 kN) ($p<0.05$).
Conclusion: The fracture strength of the metal-based complete maxillary denture with a newly designed metal framework that did not extend to the residual ridge crest was approximately two times greater than that of the resin-based denture, but its strength was lower than the strength of the conventional denture.
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Clinical Significance: The metal-based complete maxillary denture with a newly designed metal framework can be used as an alternative to a conventional metal-based complete maxillary denture.
Key Words: cobalt-chromium alloy, fracture strength, metal-based complete maxillary denture, metal framework, type of failure.

Introduction

The most commonly used material to make complete dentures in clinical prosthodontic practice is acrylic resin.[1] However, the fracture of acrylic denture bases is occasionally an unavoidable complication because the mechanical properties of acrylic resin may not be sufficient to withstand masticatory stress.[2-4] Jagger et al.[4] reported that, despite the popularity of acrylic at satisfying aesthetic demands, it is still far from ideal in fulfilling the mechanical requirements of a prosthesis. There is a great risk of fracture, particularly if the thickness of the denture base is minimal.

One of the ways to overcome this risk is to combine the acrylic denture base with a cast metal base.[5] El Ghazali et al.[6] proposed using cobalt-chromium bases in maxillary dentures to reduce the functional deformation and thrust to the supporting tissues that occur in the anterior part of the maxilla. The metal-base framework for a complete maxillary denture mainly covers the palate and residual ridges, with the borders made of acrylic resin.[5] However, it is difficult to arrange the artificial teeth in this design when there is not enough vertical distance between the upper residual ridge crest and the antagonist. The purpose of the present study was to evaluate the fracture strengths of a metal-based complete maxillary denture with a newly designed metal framework that did not extend to the residual ridge crest.

Materials and Methods

Table 1 lists the materials used in this study. Combined precision impressions of the maxillary edentulous model with no undercuts or irregularities (G1-402, Nissin Dental Products Inc., Kyoto, Japan) were made with elastomeric silicone materials (Examix Fine injection/putty type, GC Corp., Tokyo, Japan); thirty identical master casts were poured using a high-strength plaster stone (Fujirock, GC Corp.). The stone casts were randomly assigned to the following groups (n=10 each): group A, metal-based complete maxillary dentures with a conventional metal framework; group B, metal-based complete maxillary dentures with the new metal framework that did not extend to the residual ridge crest; and group C, acrylic resin-based complete maxillary dentures (control group). For groups A and B, precision impressions of each master cast were made with another silicone elastomeric material (Deguform, Dentsply-Sankin k.k., Tokyo, Japan). Twenty identical duplicate and refractory casts were formed using a rapid setting investment material (Rema Exact, Dentaurum Inc., Newtown, PA, USA) for model casting preparations in the cobalt-chromium model casting technique.

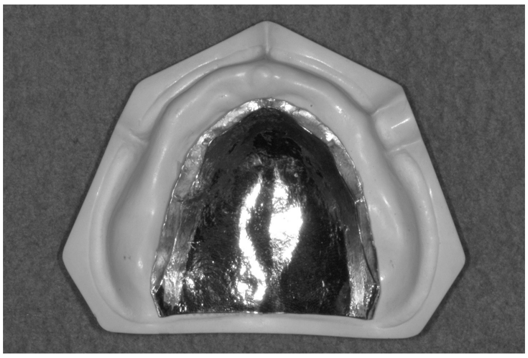
Table 1. Materials used.

Material/Trade name	Manufacturer	Batch number
Cobalt-chromium alloy		
Remanium GM380	Dentaurum Inc., Newtown, PA, USA	9930
Denture base resin		
Vertex Rapid Simplified	Vertex-Dental B.V., Oldenbarneveltlaan, Netherlands	Powder YX113P01 Liquid YW144L01
Artificial anterior resin teeth		
Gloria new ace	Yamahachi Dental Mfg., Co., Gamagori, Japan	311109
Artificial posterior resin teeth		
B.S.A. resin teeth	B.S.A. Sakurai, Co., Nagoya, Japan	LG010

The metal framework was constructed either with the new design (Fig. 1) or with a conventional design. The metal framework, which was very thin (0.3–0.4 mm), had no tissue stop and did not extend to the residual ridge crest. The retentive area of the framework had two metal plates (with a mucosal surface and a polished surface) to connect to the denture base resin (Fig. 2). Five wax rods (0.8 mm diameter) were placed vertically between the two plates at almost equal intervals horizontally in order to reinforce the two metal framework plates and to ensure the retention of the denture base resin. The denture base resin was sandwiched between the two plates, whereas in the conventional denture, the metal framework was sandwiched by the denture base resin. The conventional metal framework in this study had retention webbing that completely covered the residual ridge crest (Fig. 3) and had four tissue stops touching the alveolar tissue on the master cast to maintain its position during packing procedure (Fig. 4).

The wax patterns of both the new and the conventional metal frameworks of the metal-based complete maxillary denture were fabricated on a duplicate cast, invested with the same rapid setting investment material and burned out in the furnace according to the manufacturer's instructions. The metal framework was then cast from cobalt-chromium alloy (Remanium GM380; 64.6% Co, 29.0% Cr, 4.5% Mo, and 1.9% others; mass%) using an argon-arc melting/pressurize casting machine (Cosmos CA-100S, Casting Okamoto Inc., Imadu, Shiga, Japan).

All the cast metal frameworks were airborne-particle abraded with 50 µm grain-sized aluminum oxide particles (Aluminous Powder WA 360, Pana Heraeus Dental Inc., Osaka, Japan) using a grit blaster (Micro Blaster MB102, Comco Inc., Burbank, CA, USA) to eliminate the investment material and to clean the cast surfaces; then electrochemical polishing was performed.



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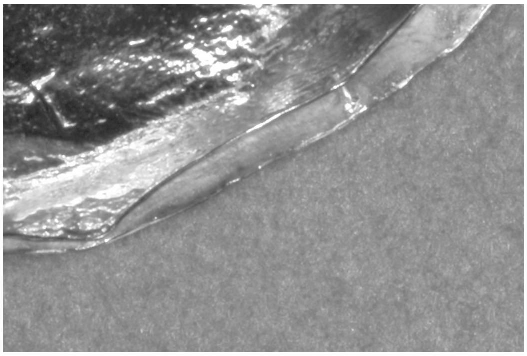

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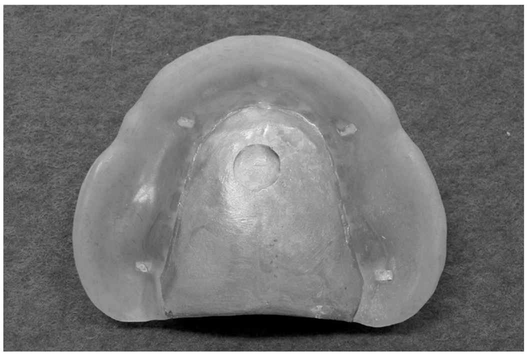

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Fig. 1. New metal framework.
Fig. 2. Peripheral retention structure of new metal framework with two plates and vertical rods to retain denture base resin.
Fig. 3. Conventional metal framework.
Fig. 4. Mucosal view of complete maxillary denture using conventional metal framework with four tissue stops.
Fig. 5. Fracture strength test using compression load assembly.

Thermoplastic sheets 4.0 mm in thickness (Erkodur, Erkodent Erick Kopp GmbH, Pfalzgrafenweiler, Germany) were used to form thermoplastic denture bases on a standard master cast by vacuum forming (Erkopress 2002, Erkodent Erick Kopp GmbH). The thickness of the thermoplastic denture bases was adjusted to 2.5 mm by careful trimming and adding wax when necessary; they were then measured with a caliper to ensure uniformity. After arrangement of the artificial teeth on the same plane using a jig custom made for this study, the metal frameworks and base plates (groups A and B) or base plate only (group C) were invested with dental stone in denture flasks. After the thermoplastic sheets were discarded and the wax was eliminated, a heat-polymerized poly(methyl methacrylate) resin was used for the denture base material. The acrylic resin polymer and monomer were mixed according to the manufacturer's instructions. Conventional packing and polymerizing procedures were performed. The dentures were processed for 15 minutes in water held at a constant temperature of 100°C and deflasked.

All dentures were stored in 37°C distilled water for 50 hours before testing. 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. A compressive load was applied to each complete maxillary denture through an 11.5 mm ball attachment (Fig. 5). The application of the downward load along the midline of the tissue surfaces of the denture was designed to be equivalent to the upward load on both sides combined with unyielding support in the center of the plate, as described by Polyzois et al.[7] All testing was performed under uniform atmospheric conditions of 23˚C and 50% relative humidity.

The mean fracture strengths of each group were statistically analyzed using a one-way analysis of variance (ANOVA) with the group as the variable. The Newman-Keuls post-hoc comparison test was applied when appropriate (95% confidence level). Types of fracture were observed in groups A and B. Types of fracture were categorized as fracture or deformation of the metal framework, fracture at the metal framework outline, or fracture of the denture base resin.

Results

The one-way ANOVA and Newman-Keuls post-hoc comparison test demonstrated that there were significant differences in the fracture strengths among the three groups ($p<0.05$). The fracture strength of group A was significantly higher than that of group B ($p<0.05$), and the fracture strength of group B was significantly higher than that of group C ($p<0.05$). The mean and standard deviations of the fracture strengths for each group with statistical categories are summarized in Table 2. The types of specimen failure after fracture testing are presented in Table 3.

Table 2. Fracture strengths for each group.

Group		Fracture strength (kN) Mean	SD	Newman-Keuls grouping
Group A	Conventional metal-based denture	2.01	0.33	a
Group B	New metal-based denture	1.49	0.24	b
Group C	Resin-based denture	0.79	0.20	c

SD: standard deviation. Identical letters indicate that the values are not statistically different ($p>0.05$).

Table 3. Type of fracture.

Type of fracture	Conventional metal framework	New metal framework
Fracture or deformation of metal framework	90%	60%
Fracture at metal framework outline	0%	40%
Fracture of base resin	10%	20%

Discussion

The main purpose of the present study was to evaluate the fracture strengths of a metal-based complete maxillary denture with a newly designed metal framework that did not extend to the residual ridge crest. The new metal framework does not disturb the arrangement of artificial teeth when the vertical distance between the upper residual ridge crest and the antagonist is insufficient. An added advantage of the proposed design is that a tissue stop,[8,9] to be positioned at a predetermined, controlled position within the prosthesis on the master cast, is unnecessary. Consequently, it is easy to adjust the mucosal surface of the denture base since the metal framework is not exposed in the denture base resin area.

The results of the fracture tests revealed that the fracture strengths of both groups A and B were significantly higher than of group C ($p<0.05$). The fracture strength of B was approximately two times greater than that of group C. This finding suggests that the new cobalt-chromium alloy metal framework may be acceptable, as well as the conventional design, for fabricating metal-based complete maxillary dentures. The fracture strengths of group B were sufficient compared with the maximal bite forces of the complete denture wearers.[10,11] However, repetitive loads may finally lead to denture fracture even if the yield strength or the proportional limit are within the acceptable range for the denture.

Fracture or deformation of the metal framework without fracture of the base resin (90% of group A and 60% of group B) indicated that the fracture strength of the framework-denture base resin connection was higher than the mean value shown in Table 2. On the other hand, fracture at the metal framework outline without fracture of the base resin (40% of group B) indicated that the stress concentration against the compressive load in the center of the plate tended to occur along this line.

Recently, the use of metal adhesive conditioners improved the bond strengths of a denture base resin to cast cobalt-chromium alloy.[12,13] It is hypothesized that good bonding of the metal framework to the denture base resin should improve the fracture strength of the metal-based denture. Therefore, further in vitro studies and clinical research are necessary to evaluate the fracture strength of the bonding system.

Conclusion

This in vitro investigation evaluated the design of the metal frameworks of complete maxillary dentures by measuring the maximum fracture strengths of the dentures. Within the limitations of the present study, the following conclusions were drawn: The strength of the metal-based complete maxillary denture with a newly designed metal framework that did not extend to the residual ridge crest was approximately two times greater than that of the resin-based denture and was lower than the strength of the conventional denture.

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