# Flexural strength of two electro-plated dental ceramics

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Karlsson S, Molin M, Myrvold T. Flexural strength of two electro-plated dental ceramics. Acta Odontol Scand 1994;52:290–293. Oslo. ISSN 0001-6357.

This study aimed to investigate the influence on flexural strength of electro-plating two dental porcelains, Vita Omega and Vita Omega 800. The porcelains were treated in accordance with the manufacturer's instructions, and the specimens were produced following the ISO 6872 standard for rectangular bars. Specimens were divided into three groups, of which none, one, or three of the surfaces were plated with a thin layer of gold. Flexural strength was tested with a three-point bending test. Ten specimens were tested for each combination of porcelain and plating, for a total of 60 test pieces. For both porcelains, a significantly higher flexural strength was found for the specimens furnished with a gold layer. The number of covered surfaces did not significantly influence the tested strength. This increase in strength is most likely due to decreased crack initiation and fracture propagation after the covering of random defects in the porcelain. A better stress distribution might also be anticipated and partly explain the results. □ *Ceramics; dental materials; dental porcelain; gold plating*

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Porcelain is an esthetic and biocompatible material well adapted, in this respect, for use in oral rehabilitation. However, a major disadvantage of dental ceramics is their susceptibility to fracture during function. When exposed to oblique forces, their physical properties, like low flexural strength, will limit their potential as posterior restoration materials. On the other hand, axial load and pressure will be tolerated very well (1, 2). The theoretical and nominal strength of porcelain is 10 to 1000 times higher than what might be expected when used in clinical practice (1). This substantially reduced strength is due to deficiencies in the manufacturing process, which will mediate a differentiated number of strength-reducing factors. The defects created in this process, like internal defects, pores, and flaws, will greatly influence the strength and physical performance of these brittle ceramic materials. Created at random, these defective sites will act as fracture initiators and thereby decrease the fracture strength of the material (3, 4).

To increase the flexural strength of an otherwise fragile ceramic material, different methods have been used, like the incorporation of a crystalline dispersion within the matrix. A core of, for example, alumina-reinforced porcelain and a metal coping are other methods recommended and used today to increase strength. Reinforcement with a metal coping in the form of a metal–ceramic full-coverage restoration is today still the commonest technique. Other methods include the placement of a metallic foil, as for the Ceplatec system, or electro-plating of the ceramic material with a thin (≈100–200 μm) metallic layer (5–7). In this manner the importance of porosities, flaws, and other fracture-disposing sites might be minimized.

Cast metallic restorations have for a long time been successfully luted with zinc phosphate cement. The introduction and increased use of ceramic inlays has, however, increased the demand for a luting system providing a laminate-type restoration with a bond between the tooth and the ceramic restoration. The assumption has been that such a procedure would increase the strength of the otherwise fragile ceramic material. Composite resin cements meet these requirements but will still require compromises in the clinical handling because of their inherent material properties (8, 9). Therefore, the clinical procedure would be facilitated if ceramic crowns and inlays could be successfully luted with zinc phosphate or glass ionomer cements instead of composite resins. A possible way to achieve this might be by reinforcing the porcelain and improving the inner and marginal adaptation to the cavities. The aim of this study was therefore to investigate the influence on flexural strength after electro-plating of two dental porcelains.

## Materials and methods

### *Specimen production*

Two sintering feldspathic ceramics recommended for bonding to metal, Vita Omega and Vita Omega 800, were used in this study. Vita Omega is a conventional high-fusing dental ceramic (fusing temperature, 930°C), and Vita Omega 800 is a low-fusing porcelain (temperature, 820°C). Body porcelain was used to produce six different series of specimens: specimens made with electro-plating of gold to the bottom surface; made with electro-plating to all surfaces except the upper one facing the applied load; and, finally, made of porcelain only. This procedure was repeated for the two porcelains Vita Omega and Vita Omega 800.

Electro-plating was performed in a special gold bath for electrolysis (Gamat dent 42, Gramm Oberflächtechnik, Tiefenbronn, Germany) following the manufacturer's instructions. By using this technique, a thin layer of gold (mean, 95 μm) was applied to one or three of the surfaces. This was achieved by producing a refractory model that, after isolation of the surfaces not to be plated, was placed in the galvanic bath.

The specimens were manufactured following the international standard for dental ceramics described in ISO 6872 (10). Ceramic powder was condensed in a separable brass mold with dimensions of 25.0 × 5.0 × 2.0 mm. The produced bars were fired and baked in an oven (Programat P 20, Ivoclar AG, Lichtenstein) in accordance with the manufacturer's instructions. Ten test pieces were made for each combination. In this manner a total of 60 specimens was produced.

Afterwards, the specimens were ground on a 40-μm diamond disc and finally polished on a 20-μm diamond disc under wet conditions, as stated in ISO 6872. A final test piece 4.0 ± 0.25 mm wide, 1.2 ± 0.2 mm thick, and at least 20 mm long was obtained. The same procedure was performed for all specimens, the plated ones included. That the surfaces were parallel and flat within 0.05 mm was checked with a micrometer. Angulation, 90° between surfaces, was ensured by examination in a profile projector (Nikon 6C-2, Nippon Kogaku K.K., Tokyo).

### *Flexural strength*

The flexural strength was tested in a three-point bending test as described in ISO 6872. A specimen was placed in a three-point bending jig, which was connected to a universal tensile testing machine, Instron 1121 (Instron Ltd., Buckinghamshire, England). For the support of the specimen, two bearers with a radius of 0.8 mm and a span width of 14 mm were used. After a specimen had been placed centrally to the bearers, a load was applied at the midpoint between the supports by means of a steel knife (radius, 0.8 mm) with a cross-head speed of 1 mm/min until the specimen fractured. Ten specimens were tested for each combination of porcelain, without and with the two types of electro-plating.

Flexural strength, $M$, in megapascals of each specimen was calculated by using the following equation:

$$M = \frac{3Wl}{bd^2}$$

where $W$ is the breaking load in newtons, $l$ is the test span (center-to-center distance between bearers) in millimeters, $b$ is the width of the specimen in millimeters, and $d$ is the thickness of the specimen in millimeters.

Table 1. Mean flexural strength ± standard deviation (MPa) and coefficient of variation (%)

| Material | Specimen* | | | | | |
|---|---|---|---|---|---|---|
| | $P_0$ | | $P_1$ | | $P_3$ | |
| Vita Omega | 77.2 ± 8.2 | 10.6 | 99.4 ± 5.9 | 6.0 | 101.2 ± 6.3 | 6.2 |
| Vita Omega 800 | 92.2 ± 9.1 | 9.7 | 118.6 ± 7.7 | 6.5 | 111.0 ± 6.2 | 5.6 |

* $P_0$ = porcelain only; $P_1$ = porcelain and gold at the bottom surface; $P_3$ = porcelain and three gold-plated surfaces.

### Statistics

The significance of differences between pairs of tested means for plated and unplated porcelains was tested with a two-tailed Student's *t* test. One-way analysis of ANOVA was applied for testing differences between mode of gold-plating and type of porcelain and flexural strength.

## Results

A higher flexural strength was registered for the plated specimens (Table 1). This difference in flexural strength was significant between the plated and unplated specimens for both Vita Omega and Vita Omega 800 ($P < 0.001$). The number of electro-plated surfaces, regardless of the ceramic material tested, did not significantly influence the flexural strength expressed by this three-point bending test.

For all tested combinations, the Vita Omega 800 porcelain showed significantly (at the 95% level, ANOVA) higher flexural strength values than Vita Omega.

The coefficient of variance (COV) had a similar range for both Vita Omega and Vita Omega 800, with higher values for porcelain without electro-plating.

## Discussion

The presented results show that a significant increase in flexural strength values was achieved after electro-plating of the ceramic specimens. There was, however, no difference related to the number of surfaces plated. This indicates, as expected, that the bottom surface, when exposed to tension in a three-point bending test, is the most important one in crack initiation and fracture propagation.

Defects in the porcelain, pores and micro-cracks, are properties of great importance for the strength and clinical application of ceramics in dental practice. A surface area containing these flaws will in addition be significantly less able to withstand stress and strain (11). Apparently, the application of a thin gold layer to the most critical surface was beneficial to flexural strength, which increased significantly. This effect might also be anticipated after glazing, a procedure less suitable for a surface facing the tooth substance, however. The influence of structural defects as fracture initiators will decrease when they are covered by an even layer of metal. This layer will probably serve as a stress distributor and thereby act as an inhibitor of crack initiation and propagation. An increased strength of ceramic crowns after plating with a thin gold foil has been reported earlier (5).

The fracture strength of a ceramic material is statistical to its nature, depending on the distribution of pores and other defects that may act as fracture initiators. As expressed by the coefficient of variation (COV), a greater variability was found for the porcelains not covered by a gold layer. This finding could be seen as a result of the gold layer acting as an eliminator of some of the fracture sites in the ceramic material. This lower COV found for the plated specimens is a further indication of the strengthening achieved by decreasing the influence of inherent surface defects. The COV found in this study, 6–11%, is well within the range that others have reported for dental porcelains (12).

A general belief today is that ceramics used in dentistry do not fracture or fail as a result of high-impact instant loading. On the contrary, low-energy flexural forces and static fatigue of the material, concentrated to the defective sites, will over time result in failure. Therefore, lamination with a layer of, for example, metal may contribute to an increased strength also in the long term and eliminate some of the negative factors connected with luting with a non-adhesive technique.

In general, higher flexural strength values were found for the specimens that had been gold-plated, and the highest value was found for Vita Omega 800 with the bottom surface gold-plated. The latter is a low-fusing porcelain and as such normally less resistant to flexural load. A possible explanation for its higher strength than Vita Omega might be another composition of the glass matrix, decreasing the number of internal and external defects in the material.

Only clinical studies can determine the usefulness of this method for increasing the strength of porcelain bridges, crowns, and inlays, however. The application of this technique in clinical practice will therefore be evaluated in a forthcoming study.

Received for publication 18 February 1994
Accepted 22 March 1994

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