# Strength, hardness, corrosion evaluation and computer-aided designing of cobalt–-chromium molybdenum maxillary major connectors. (Part I)

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## ABSTRACT

**Background:** Rigidity is one of the main criteria for the major connector. This study was conducted to determine the effect of width and thickness on the rigidity of single palatal strap major connector using two cobalt–chromium molybdenum (Co–Cr–Mo) alloys, Remanium and Biosil cast by two different techniques, electrical induction–melting, and gas–oxygen torch melting on the transverse strength of maxillary major connectors.
**Materials and methods:** Forty–eight specimens for transverse strength, twenty–four specimens for hardness, and twenty–four specimens for corrosion were prepared, examined by x–ray then tested by engineering test equipment, hardness tester, and sensitive electronic balance respectively. Ion release into saliva was tested by Atomic Absorption Spectrophotometer and chemical methods.
**Results**: There was a statistically significant effect of each of the products, casting techniques, width (4&8)mm and thickness (0.4&0.6)mm on the transverse strength of Co–Cr–Mo single palatal strap major connector and statistically significant effect of each of products and casting techniques on hardness of Co–Cr–Mo alloy, but results of corrosion and ion release tests were insignificant.
**Conclusions:** The major connector made from Remanium cast by induction technique produces stronger and harder specimens. The effect of thickness is more significant than the width, and there was no significant change in weight after 760 hours immersion in saliva.
**Keywords:** Strength, corrosion, cobalt-chromium–molybdenum. **(J Coll Dentistry 2005; 17(1) 24-29)**

## INTRODUCTION

The importance of properly designed removable partial dentures (RPDs) can not be over emphasized. The execution of a RPD design may determine the success, or failure of the appliance. [(1, 2)] The palatal strap is the most versatile maxillary major connector. It can be made fairly narrow antero-posteriorly for a tooth–supported denture when the edentulous spaces are small. The width should be increased as the e[1]dentulous space increases in length. This not only ensures rigidity, but also provides greater support. [(3)]

The dentist is the only one who can make the proper decision involved in the treatment plan and design of a RPD. The technician can not decide what is biologically acceptable for a patient. [(4)]

If the material is deformed by a stress to a point above the proportional limit before fracture, the removal of the applied force will reduce the stress to zero but the object does not return to its original dimension. It remains bent, stretched, compressed or otherwise plastically deformed, and is thus clinically useless [(5)]. Hardness is indicative of the ease of finishing and polishing of a structure and its resistance to in–service scratching. Scratches can compromise fatigue strength and lead to premature failure. [(6)] The major requirement of any metal and alloy used in the mouth is that it should have good corrosion resistance. [(7)]Corrosion, if noticeable, can alter the physical, and mechanical properties, and reduce the denture's esthetic value. [(8, 9)] Atomic Absorption Spectrophotometer (AAS) is a very sensitive technique for the determination of ion and it can be utilized in qualitative and quantitative analysis. [(10, 11)]

The melting of base metal alloy must be carefully controlled to avoid severe damage to the alloy. More severe damage is not uncommon and results from excessive overheating and resulting porosities and surface reactions with the mold materials. [(12)] It would be preferable to test dental casting prior to use as their subsequent failure could give rise to serious problems. The most obvious choice is radiographic technique. [(13)]

The purposes of this study were to evaluate the transverse strength, hardness, corrosion, and ion release of Co–Cr–Mo alloy of single palatal strap major connector cobalt–chromium

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molybdenum of two products with two widths and thicknesses, and two casting techniques.

## MATERIALS AND METHODS

A rubber mold for standard maxillary dental arch (Frasaco, Germany) was used to produce two maxillary dentate casts of die stone (Silky Rock, Whipmix, USA). The second premolar and first molar on both sides of the two casts were removed to produce a typical indication of single palatal strap major connector. [14] The two resultant saddle areas were beveled [17] by a disk mounted on a handpiece which in turn mounted on a surveyor. On one of them, single palatal strap major connectors of 4mm, & 8mm antero-posterior width (at the midline) were outlined. [15] Each of the two master casts was duplicated 24 times with agar duplicating material (Geloform, Degussa, Germany) to produce 48 refractory casts from phosphate–bonded investment especially manufactured for Co–Cr–Mo casting (Rema Exact, Dentaurum, Germany).

Model hardener (Dentaurum, Germany) was used to seal the surface of the casts. Waxing was done by using maximum thickness [22–gauge (0.6 mm)], and minimum thickness [24–gauge (0.4 mm)]. [14] Two sprues (2 cm length and 3.5 mm diameter) were added at the area of the junction between the major and minor connectors. The length, diameter and number of sprues were determined from pilot study. The results showed that no difference between using 2 or 3 sprues. And longer sprues can be used with no spaces for sprue button former.

Two Co–Cr–Mo dental casting alloys (Remanium, Dentaurum, Germany; and Biosil, Degussa, Germany) and two different casting machines were used. Neutrodyne Easyti, Manfredi, Italy is an electronic, induction–melting, centrifugal casting machine. And Motorcast, Degussa, Germany is centrifugal casting machine with motor drive and double articulated arm for melting with an open flame melting was done by using blowpipe.

After casting and sandblasting, the sprues were cut without touching the framework [16]. The casting was placed in polishing bath unit using polishing bath solution for 10 minutes. Thickness of casting was checked by vernia (Lezaco Art. 2771, China) with accuracy of 0.01 mm to ensure uniform thickness. Dental x–ray apparatus (Trophy, France) was used in conjunction with an occlusal dental x–ray film (Dentus, Agfa, Belgium). The exposure was made at 15 mA and 65 kV for 180 impulses according to pilot study. [17] The radiographs were examined for evidence of change in density more than 5% indicates inhomogeneous [18] of metal by using digital transmission densitometer (DT 1105, England).

The transverse strength (three point bending test) is essential to determine the strength of the material and the amount of distortion expected. The transverse strength test is a part of ANSI / ADA specification No.12 for denture base resins. [16,19]

Each major connector specimen was tested on engineering test equipment [compression testing machine] (Model CN 472, USA) with an accuracy of 0.001 inch. The specimen was placed at the base of the machine and a chisel–like rod that was fitted to the top part of the machine (where the loading cell was mounted) was used to induce the bending force. According to Ben–Ur *et al*.[20] forces in multiple of 5N were added, and the degree of distortion was measured.

The property of hardness and corrosion of two Co–Cr–Mo products were done on twenty four specimens (20 mm length, 10 mm width, and 0.6 mm thickness). Rockwell hardness values were determined by a hardness tester (WOLPERT, Germany) according to ADA Specification No. 14 for dental cobalt–chromium casting alloy, [21] five locations were randomly chosen near the center of each specimen and were measured and their main value was computed as the hardness of the specimen.

Each specimen was weighed by a sensitive electronic balance (Melter PM 460, Switzerland) with sensitivity of 0.001g and placed in a sterile vial containing natural saliva from the same person. The twenty four vials were placed in an incubator at a temperature of 37 ºC.[22] The immersion period was 720 hours; then the specimens were weighed again by the same balance to determine whether there is loss in weight. Ion release test was done by two methods

(1) Atomic Absorption Spectrophotometer (AAS), and

(2) The chemical methods by adding ammonia or sodium hydroxide solution to see whether there is a change in color which indicates the presence of Co and / or Cr ions. Analysis of variance test (ANOVA) coupled with Duncan's Multiple Range Test was used to

show how the difference among groups is arranged at a significant level of $p \leq 0.05$.

## RESULTS

Mean and standard deviation for product type, casting technique, width, and thickness of transverse strength were shown in Table (1). In order to test whether there is any significant difference among these variables on force on single palatal strap major connector, one way interaction ANOVA was performed (Table 2), interaction of product type, casting technique, width, and thickness, Duncan's Multiple Range Test was used to statistically isolate the most rigid major connector based on the studied variables (Figures 1&2, Table 3).

Mean of hardness and standard deviation of product type and casting technique are shown in Table (4). In order to test whether there is any significant differences between product types and casting technique on hardness, analysis of variance tests were performed (Tables 5). Duncan's Multiple Range Test was used to statistically isolate the group that shows the greater hardness (Table 6).

The specimens for corrosion test were weighed again after elapsing 720 hours immersed and their weights were recorded and compared with their previous weights before immersion. There were no significant changes in weight (Table 7). The samples of saliva (in which specimens of corrosion were immersed) were tested by AAS and results indicated that there was neither release of Co, nor Cr ions into saliva.

## DISCUSSION

The results of transverse strength showed that width, and thickness of major connector has high significant effect on force on major connector and this is in agreement with Eto *et al*.[15] Other researchers concluded that major connector with different narrowed cross sections were significantly more flexible than thicker major connectors[23,24]. The results showed that the effect of thickness is more significant than the effect of width. The length and thickness of major connector are critical because the deformation varies as the cube of these two dimensions. [16] Results also showed high significant effect of casting technique on force on major connector. [25]

It was recognized that a pronounced variation in properties of a final casting may result from the use of variable casting conditions. The base metal alloys are known as technique sensitive alloys. [26] The main damage is caused by the rapid heat transfer from the flame which is at a temperature several hundred degrees centigrade higher than the melting range of the alloy. The result is that the alloy reaches the zone of partial or total overheating [27]. The grain size, dendrite structure, and carbide present in the casting are all affected by flame. The minor alloying elements of carbon, nitrogen and oxygen mainly influence the casting. Oxidation of the ingredient metals and carbide or nitride formation cause severe damage to the properties of casting. If proper melting particles are not observed more severe damage is not uncommon and results from excessive overheating and resulting porosities and surface reactions with the mold materials.[28]

Specimens that were cast by induction melting technique had the highest hardness number with high significant difference from specimens cast by torch melting technique.[25] This might be explained by the changes of grain size, dendrite structure, and the diffusion of oxygen during casting.

Many researchers studied corrosion and ion release of base metal alloy and other alloys in environment such as in cleansers,[11] the more interesting point to consider is the corrosion and ion release of Co–Cr alloy in the common condition which is the ordinary construction of RPD and in the usual environment in the oral cavity.

It is clear that as the immersion period lengthened in distilled water, the chance for any change (if occurs) will increase, so we used one month immersion period [10].Localized corrosion may occur because of the casting inclusions with the possible incorporation of contaminants during the casting process. [5]For these two reasons, two different casting techniques were considered in this study.

Results showed that there were no significant changes in weight (Table 7) in any group tested and this may be explained either by the high corrosion resistance property of Co–Cr–Mo alloy regardless of the casting technique or the immersion period must be extended although the immersion period used in this study was longer than that used by other researchers [29], and this may be explained by the conditioning medium that was used. In the present study, natural saliva was used, while other studies used different types of conditioning media varying in pH, salt and protein contents, which may result in greater element release from the surface of the alloy. Molybdenum, nowadays, became an integral component in Co–Cr alloy which is, nowadays, called Co–Cr–Mo alloy. Molybdenum prevents intra-granular corrosion and surface pitting as well as aiding the homogeneity of the alloy.

To support the results of weight loss, ion release was tested quantitatively by AAS, and qualitatively by chemical methods. The results were not significant which are in agreement with Al–Hiyasat *et al*., (10) but not in agreement with Stenberg. (29)

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**Table (1): Mean and standard deviation of product, technique, width and thickness for transverse strength test.**

| | | Mean (N/in) | Standard Deviation |
|---|---|---|---|
| Product | Remanium | 61.5000 | 35.1879 |
| | Biosil | 51.2500 | 26.3443 |
| Technique | Induction | 59.4444 | 31.8148 |
| | Torch | 54.4444 | 31.9956 |
| Width (mm) | 4 | 38.7500 | 16.2354 |
| | 8 | 71.5000 | 33.6859 |
| Thickness (mm) | 0.4 (24–Gauge) | 29.3750 | 12.0066 |
| | 0.6 (22–Gauge) | 79.0000 | 24.2970 |

**Table (2): ANOVA test for transverse strength, one–way interaction.**

| Source | Sum of Squares | Degree of Freedom | Mean Square | F–value | *p*–value |
|---|---|---|---|---|---|
| Product | 4240.370 | 1 | 4240.370 | 6.888 | 0.011* |
| Technique | 10696.296 | 1 | 10696.296 | 21.763 | 0.000** |
| Width | 14300.833 | 1 | 14300.833 | 19.082 | 0.000** |
| Thickness | 32835.208 | 1 | 32835.208 | 83.552 | 0.000** |

* Significant, ** highly significant.

**Table (3): Duncan Multiple Range Test for the interaction among product, technique, width and thickness.**

| Product | Technique | 4 mm Width | | 8 mm Width | |
|---|---|---|---|---|---|
| | | Thickness | | Thickness | |
| | | 0.4 mm | 0.6 mm | 0.4 mm | 0.6 mm |
| Remanium | Induction | 30.0 ± 8.53 $^{c–f}$ | 45.0 ± 8.53 $^{b–e}$ | 85.0 ± 6.03 $^{a}$ | 95.0 ± 8.53 $^{a}$ |
| | Torch | 35.0 ± 8.53 $^{b–f}$ | 50.0 ± 8.53 $^{bcd}$ | 25.0 ± 8.53 $^{def}$ | 85.0 ± 8.53 $^{a}$ |
| Biosil | Induction | 15.0 ± 8.53 $^{f}$ | 55.0 ± 8.53 $^{bc}$ | 20.0 ± 8.53 $^{ef}$ | 92.5 ± 6.01 $^{a}$ |
| | Torch | 20.0 ± 8.53 $^{ef}$ | 60.0 ± 8.53 $^{b}$ | 40.0 ± 8.53 $^{b–f}$ | 95.0 ± 8.35 $^{a}$ |

Different letters mean significant difference at $p \leq 0.05$.

**Table (4): Mean and standard deviation of product and technique for hardness test.**

| | | Mean (RHN) | Standard Deviation |
|---|---|---|---|
| Product | Remanium | 112.4681 | 3.3287 |
| | Biosil | 113.8723 | 3.6690 |
| Technique | Remanium | 114.1667 | 3.4042 |
| | Biosil | 112.1304 | 3.4423 |

**Table (5): ANOVA test for hardness, one–way interaction.**

| Source | Sum of Squares | Degree of Freedom | Mean Square | F–value | *p*–value |
|---|---|---|---|---|---|
| Product | 46.34 | 1 | 46.34 | 3.776 | 0.05* |
| Technique | 97.393 | 1 | 97.393 | 8.313 | 0.005** |

* Significant, ** highly significant.

**Table (6): Duncan Multiple Range Test for the interaction between product and technique in hardness test.**

| Product | Technique | Mean | Standard Deviation | Duncan Group |
|---|---|---|---|---|
| Remanium | Induction | 113.50 | 0.44 | A |
| | Biosil | 111.39 | 0.83 | B |
| Biosil | Induction | 114.83 | 0.87 | A |
| | Biosil | 112.87 | 0.56 | AB |

Different letters mean significant difference at $p \leq 0.05$.

**Table (7): Results of corrosion test .**

| Specimen No. | Weight before immersion | Weight after immersion | Specimen No. | Weight before immersion | Weight after immersion |
|---|---|---|---|---|---|
| 1. Rem. Ind. | 0.645 | 0.644 | 13. Biosil. Ind. | 0.645 | 0.644 |
| 2. Rem. Ind. | 0.609 | 0.609 | 14.Biosil. Ind | 0.609 | 0.609 |
| 3. Rem. Ind. | 0.713 | 0.712 | 15.Biosil. Ind. | 0.713 | 0.712 |
| 4. Rem. Ind. | 0.693 | 0.692 | 16.Biosil. Ind. | 0.693 | 0.692 |
| 5. Rem. Ind. | 0.580 | 0.580 | 17.Biosil. Ind. | 0.580 | 0.580 |
| 6. Rem. Ind. | 0.664 | 0.664 | 18.Biosil. Ind. | 0.664 | 0.664 |
| 7. Rem. Torch | 0.565 | 0.565 | 19.Biosil Torch | 0.565 | 0.565 |
| 8. Rem. Torch | 0.618 | 0.619 | 20.Biosil Torch | 0.618 | 0.619 |
| 9. Rem. Torch | 0.657 | 0.658 | 21.Biosil Torch | 0.657 | 0.658 |
| 10. Rem. Torch | 0.549 | 0.549 | 22.Biosil Torch | 0.549 | 0.549 |
| 11. Rem. Torch | 0.698 | 0.698 | 23.Biosil Torch | 0.698 | 0.698 |
| 12. Rem. Torch | 0.565 | 0.561 | 24.Biosil Torch | 0.565 | 0.561 |

**Rem.Remanium**
**Ind. Induction**

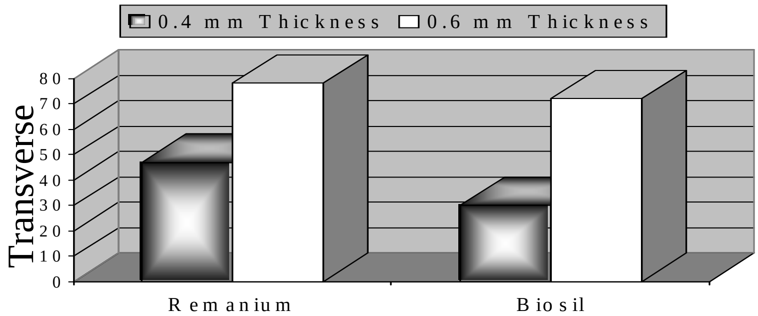


**Figure (1): Effect of interaction between casting technique and width on transverse strength of major connector.**

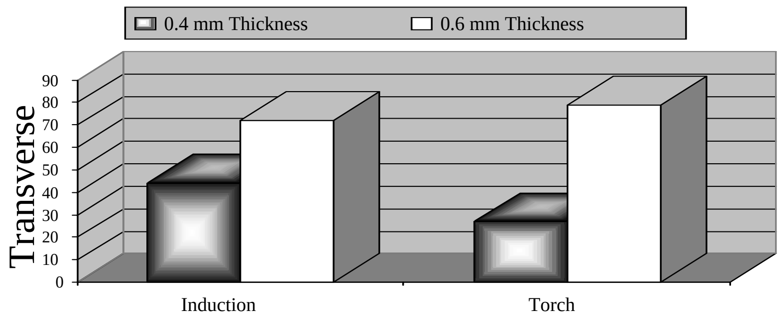


**Figure (2): Effect of interaction between casting technique and thickness.**