



# Reducing the alloy thickness of base metal ceramic restorations

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## ABSTRACT

### Statement of problem:

Reduction in base metal alloy thickness will permit additional porcelain depth and improved aesthetics but unfortunately little information exists regarding the thickness to which base metal alloys may be reduced in comparison to noble metal alloys for metal ceramic restorations. Even with comparison of noble metal alloys the aesthetic benefits are restricted to improving aesthetics in base metal restoration further, since noble metal alloys are generally regarded as providing superior aesthetics to base metal restorative alloys.

### Purpose:

The objective of this study was to determine whether a significant reduction in thickness could be achieved using a base metal alloy as compared to a noble metal alloy and the thickness to which base metal alloy substructures could safely be reduced while still providing the same resistance to fracture of the porcelain.

### Material and methods:

Tensile strength tests (N) of the modulus of rupture of the porcelain were performed on 40 base metal alloy (Wiron 99, Bego, Germany) and 12 noble metal alloy rectangular specimens (5.8 mm wide and 15.0 mm long) bonded to a standardized 1.0 mm thickness of dentine Creation porcelain. The base metal alloy thickness varied in 0.1mm increments from 0.1 to 0.4 mm. The results were compared to 12 noble metal alloy (Bio Y 81, Argon, South Africa) specimens of recommended minimum thickness (0.3 mm). Data for the results was obtained using a universal tensile testing instrument, which was set to operate at a cross head speed of 0.5mm (Instron Mini 44, Instron corporation U.S.A). The applied force (N) that measured the modulus of rupture of each specimen was printed from a computer connected to the Instron Mini 44 that operated on a 95% level of confidence. Instron Agents (Durban, South Africa) performed the calibration and setting up of the machine prior to testing the specimens.

### Results:

The results indicated a permissible 33.33% reduction in the base metal alloy specimens as compared to the noble metal alloy control specimens. This was deduced from the reduction in alloy thickness of up to 0.2 mm for base metal alloy specimens as compared to the 0.3 mm noble metal alloy specimens. The recommended thickness to which the base metal alloys could be reduced without distortion of the alloy was also 0.2 mm. The one-way ANOVA showed a level of significance of ( $\alpha=05$ ).

## INTRODUCTION

Base metal alloys have become popular as an alternative to noble metal alloys and are being used more extensively than any other metal alloys.<sup>1</sup> Although initially introduced mainly because of the high increase in the cost of gold, the success experienced when using base metal alloys due to their superior physical properties regarding yield strength and modulus of elasticity may have added benefit.<sup>2-5</sup>

This *in vitro* study was designed to determine the extent to which these properties can be beneficial in allowing a reduction in base metal alloy thickness.<sup>3</sup> The method of porcelain fracture is a complex phenomenon and experiments of this type are complex *in vitro*, and even more taxing *in vivo*.<sup>6-14</sup> This study compared a base metal alloy of varying thickness (increasing linearly in 0.1 mm intervals from 0.1 mm to 0.4mm) to a noble metal alloy 0.3 mm thick.

The objective of this study was to determine whether a significant reduction in thickness could be achieved using a base metal alloy while providing equivalent fracture resistance to recommended thickness of a noble metal alloy. It is hoped that the results of this study will also produce an awareness of the difference that an additional small reductions in tooth preparation might make to the final strength and aesthetic requirements of the restoration as opposed to just solving the problem of providing sufficient alloy support for the porcelain by replacing noble metal alloys with base metal alloys.

## MATERIAL AND METHODS

A total of 40 base metal alloy specimens (Wiron 99, Bego, Germany) and 12 Noble metal alloy specimens (Bio Y 81, Argen, South Africa) were tested using a universal tensile testing instrument (Instron Mini 44, Instron corporation U.S.A; With loading parameters of 0-500 N). The tensile strength of porcelain was measured. This strength is maximized in the lower curved surface of the loaded beam. Hence this study used the 3-point bending test whereby the third point of the loaded beam contacted the metal alloy surface, thereby exposing the ceramic material to maximum tensile force.

In order to measure the tensile strength and not compressive strengths of porcelain, it was necessary to place the samples

with the porcelain surface facing downward. The sample rested on two flat smooth metal surfaces 10mm apart on either side with a third point, measuring the fracture resistance in N, being lowered from above onto the middle of the alloy surface of the sample. As this third point started bending the sample in the direction of the porcelain surface, this surface was bent outward placing the porcelain in tension. The samples were not deformed after the test, showing only a hairline crack produced as a result of just reaching the modulus of rupture value.

The Instron 44 tensile testing machine was set to operate at a cross-head speed of 0,5 mm per minute. The samples were placed with the porcelain surface facing downward resting between two smooth metal plates 10mm apart, to allow free rotation during testing. As soon as the porcelain cracked at the modulus of rupture, a reading of force resisted in N was recorded for each sample.

The reduction of thickness for base metal alloy samples as compared to noble metal alloys was established by finding the base metal alloy specimen group that provided the same support to resist porcelain fracture as the noble metal alloy specimen group. Comparing the thickness of these base metal alloy specimens to those of the noble metal alloy specimens gave an indication of the thickness to which base metal alloy substructures can be reduced. This study compared a base metal alloy of varying thickness (increasing linearly in 0.1 mm intervals from 0.1 mm to 0.4mm) to a noble metal alloy control 0.3 mm thick (Table 1).

All the specimens including the noble metal alloy were cast (Using a gass oxygen torch and centrifugal casting method) from 0.4 mm thick smooth wax (Dentaurum, Germany). Each specimen was then carefully trimmed to the desired thickness and rectangular size (5.8 mm wide and 15.0 mm long).

Number of specimens	Group of specimens	Alloy thickness	Porcelain thickness	Combined thickness
12 Noble metal	Control group	0.3mm	1.0mm	1.3mm
10 Base metal	A group	0.1mm	1.0mm	1.1mm
10 Base metal	B group	0.2mm	1.0mm	1.2mm
10 Base metal	C group	0.3mm	1.0mm	1.3mm
10 Base metal	D group	0.4mm	1.0mm	1.4mm

All samples were fired in sample batches in order to allow identification and to prevent mixing them up. They were

stored in containers marked clearly with the alloy thickness. Layering was performed using a layering depth gauge into which the alloy specimens just fitted. This allowed exactly the same dimensions of porcelain to be applied regarding length and breadth of sample, resulting in consistent amounts of porcelain for each sample group. The opaque specimen was placed in the depth gauge, after zeroing the digital display of the depth gauge when the plunger was level with the outer surface. As the plunger descended, the depth was indicated on the LCD display. The depth gauge was used to get more consistent amounts of porcelain on the metal alloy surface to ensure that firing shrinkage and porcelain thickness for each sample group were consistent.

The technique used allowed the correct amount of porcelain to be built up so that after firing the samples had marginally thicker porcelain depths than was planned for after the one bake method used. This was necessary because the centre of the samples seemed to shrink slightly more and the edges were then trimmed slightly to create the constant thickness of porcelain required.

The depth gauge chosen utilized a modified digital vernier with an LCD display and accuracy of approximately 0,03mm. By subtracting the thickness of the alloy porcelain depth could be calculated and the desired thickness of alloy and porcelain combination was obtained. These measurements were confirmed using a thickness gauge.

## RESULTS

Figure 1 shows a graphical representation of the strength values of porcelain when the alloy thickness was varied. The mean values N for each specimen group are shown. The results from each specimen were compared with those of the control group (Table 2). All values are expressed as high, mean and low. The control group (0.3 mm alloy thickness and 1.0 mm porcelain thickness) was used to determine the possible reduction in thickness of base metal alloys compared to noble metal alloys. Figure 1 shows the mean strength values in N of base metal alloy thickness variations while the porcelain thickness was constant at 1.0 mm. The control group gave a mean result of 35,67 N with a lower end value of 28,09 N and a highest value of 41,60 N. The standard deviation of the control group was 4.01 N. The control group produced a lowest value

of 28.09 N. Since this lowest value just fell within the low strength value of the control group, all the base metal alloy specimens above 28.09 N were accepted as having strength values above that of the noble metal alloy control group. The base metal alloy specimens with lower strength values than 28.09 N would allow the porcelain to fracture with less applied force than the noble metal alloy control group. Only group B, table 2 therefore provided values, which could indicate the permissible thickness reduction of the base metal alloy specimens when compared to specimens of the noble metal alloy control group.

	CONTROL	A	B	C	D
High	41.60 N	39.72 N	42.75 N	44.72 N	47.73 N
Mean	35.67 N	33.32 N	35.17 N	38.86 N	45.77 N
Low	28.09 N	26.75 N	28.46 N	32.21 N	43.70 N
Std. Deviation	4.01	4.61	4.50	4.26	1.46
Coefficient of variance	11.24%	13.84%	12.79%	10.96%	3.19%

Table 2: Strength of porcelain to resist fracture (N) measurements of specimens for metal alloy thickness variations

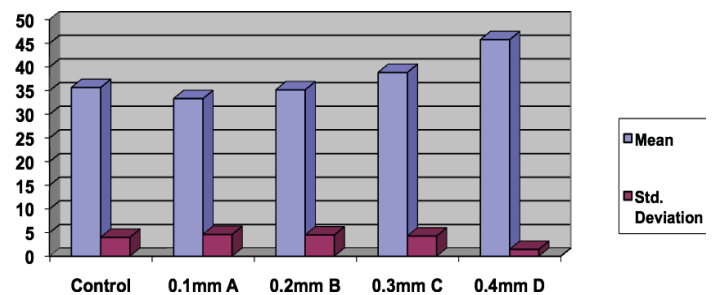


Figure 1. Strength values N and standard of deviation, for the ability of porcelain to resist fracture.

The 0.4 mm base metal alloy specimens, being the thickest, provided more than an adequate strength as all the specimens were above 40.00 N. The 0.2 mm and 0.3 mm alloy specimens also showed strength values above the control group's lowest value of 28.09 N, with the 0.2 mm base metal alloy's lowest value being 28.48 N and the 0.3 mm specimens having a lowest value of 32.21 N. The 0.1 mm specimens had a low strength value of 26.75 N, and did not meet the minimum strength values of 28,09 N established by the noble metal alloy control group. The 0.1mm specimens were also the only specimens

that distorted to an unacceptable extent during working and firing procedures.

One way ANOVA statistics that compared the strength values of the noble metal alloy control group and that of the base metal alloy specimen groups differed significantly ( $\alpha=05$ ).

The results (Table 2), did not present a linear progression in the ability of porcelain to resist fracture as a linear increase of base metal alloy thickness was tested. In order to test the hypothesis it was necessary to establish which group most closely represented the same results as the noble metal control. Only group B presented similar strength values to that of the noble metal alloy control (Table 2).

## DISCUSSION

The hypothesis, that a significant reduction in thickness can be achieved using a base metal alloy when compared to the strength of a noble metal alloy was accepted. The results in Table 2 show that if the porcelain thickness is at the minimum permissible thickness to match a shade of 1.0 mm the alloy should not be reduced to below 0,2 mm. This allows a significant 33.3% reduction of 0.1 mm from the thickness of the noble metal alloy control group (of 0.3 mm). Specimens were limited to one design that was tested *in vitro* and not *in vivo*.

The results in Table 2 further show that increasing the metal alloy thickness increased the metal ceramic restoration's strength markedly even though there was not a linear relationship regarding strength values and alloy thickness when the metal alloy thickness was increased linearly and the porcelain thickness remained constant (figure 1). The importance of the coefficient of variation values was that they indicate the minimal variation of the specimens (Table 2). The quality of manufacture was influenced by the thickness of the base metal alloy. The 0.4 mm specimen group showed smaller Standard of deviation than the other specimen groups of only 1.46 as compared to 4.26 and above for the 0.1, 0.2, and 0.3 mm specimen groups (Figure 1). This indicates that if sufficient base metal alloy thickness of a minimum of 0.4 mm is allowed for the alloy thickness, it allows the restoration to resist porcelain fracture better (with a smaller standard of deviation). As a result, 1.4 mm of space would be required to be able to start producing more predictable results and hopefully

reduce the percentage of unexplained clinical fractures through increased reproducibility.

The permissible reduction of base metal alloy did not allow a without risk reduction of up to 0.1 mm as Weiss<sup>32</sup> suggests is possible, as the minimum strength values for some specimens were below that of the clinical standard of the control group. These 0.1mm base metal alloys were also observed to distort due to working and firing procedures and are therefore not recommended for practical use. It cannot however be said with certainty that reducing the metal alloy to 0.1 mm will result in fracture, since this may depend on design and *in vivo* function.

From the results obtained it could be argued that the alloy thickness is the main contributing factor to enhancing the strength of metal ceramic restorations. The alloy thickness needs to be as thick as possible when the porcelain thickness is at a minimum of 1.0 mm in order to just be able to gain satisfactory reproducibility in strength. Where there is sufficient space available, indications are to maximize the alloy thickness as soon as there is sufficient porcelain depth for aesthetics. From the results it would appear that less than 1.2 mm of available space is insufficient to obtain required strength and aesthetic characteristics. Future research needs to be conducted *in vivo* to establish clinical performance and the strength contribution of porcelain thickness variation.

## CONCLUSION

Using base metal alloys may result in a substantial reduction in alloy thickness provided that the thickness is not reduced to below 0.2 mm. This reduction may improve aesthetics in base metal alloys but will not necessarily be an improvement on noble metal alloy aesthetics. Knowing the minimum permissible thickness for base metal alloys is important where space constraints are extreme but should not be utilized as a rule since adequate space for alloy and porcelain will improve the ability of porcelain to resist fracture and provide a smaller standard of deviation. Thus the quality of manufacture of the metal ceramic restoration will be improved.

The nature of tensile strength measurement was simplified to a one specimen design. Therefore no information was provided about the performance due to variations of design, material and

type of loading, or the long-term performance of restorations *in vivo*.<sup>15, 16</sup>. The base metal alloy specimens could be reduced to 0.2 mm and still resist fracture of the porcelain to a similar extent as the 0.3 mm noble metal alloy specimens when a tensile force was applied. This would suggest that the base metal alloys specimens could be reduced by 33.33% in alloy thickness as compared to the noble metal alloy specimens. This possible reduction in thickness using a base metal alloy as opposed to a noble metal alloy was only applicable to the 0.3 mm noble metal alloy specimens and the 0.2 mm base metal alloy specimens.

There was not a linear relationship regarding strength values and alloy thickness, even though the metal alloy thickness was increased linearly and the porcelain thickness remained constant. As a result possible alloy thickness reductions when using base metal alloy instead of noble metal where the noble metal alloy thickness varies from the 0.3 mm thickness could not be deduced from the results.

Comparing a base metal alloys with of a noble metal alloy resulted in establishing a substantial permissible increase in porcelain depth and reduction in based metal alloy thickness, provided that the thickness is not reduced to below 0.2 mm. The clinical implication of this study would therefore be a possible 0.1 mm reduction from 0.3 mm thickness. Although this permissible reduction in base metal alloy doesn't seem to be much, it might be half the thickness of a 0.2 mm opaque layer and is important in establishing minimum thickness safety guidelines. It is hoped that the results of this study will produce an awareness of the difference that an additional small reductions in tooth preparation might make to the final strength of the restoration as opposed to just solving the problem by reducing the base metal alloy thickness to a permissible minimum.

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