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Review Article

Marginal discrepancy in base metal alloys: A systematic review and meta analysis

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ABSTRACT

Marginal discrepancy in crowns and bridges can pave way to secondary caries, endodontal, periodontal problems, etc. As marginal discrepancy is also influenced by the type of alloy used, it was decided to review systematically the influence of different alloys on marginal discrepancy. The study is to compare and evaluate the amount of marginal discrepancy in complete veneer crowns fabricated using base metal and noble metal alloy. An electronic search was initiated for scholarly articles on crowns and bridges, base metal alloys crowns, noble metal alloy crowns and marginal discrepancy. The search was PubMed based. The search methodology applied was a combination of MESH terms and suitable keywords based on PICO formulated for the review. Suitable keywords were formulated for PICO and subjected to advanced search using Boolean operators. The search strategy yielded 17 articles. 6 were excluded following reading extract and 11 were selected for full-text reading. Of these 6 were excluded based on exclusion criteria. Finally, 5 articles were included for final search. Data extraction was done from the selected articles. The extracted data were analyzed statistically. The mean marginal discrepancy incurred by base metal alloy was 125.7 ± 43.03. The mean marginal discrepancy incurred by noble metal alloy was 56.723 ± 34.14. Meta analysis showed a statistically significant difference in the amount of marginal discrepancy incurred by base metal alloys than noble metal alloys with overall effect size of $Z = 7.57$, $P < 0.00001$, respectively. This study revealed that the base metal alloys incurred more marginal discrepancy than noble metal alloys. However, the marginal discrepancy incurred is considered clinically acceptable.

Keywords: Base metal alloys, complete veneer crowns, marginal discrepancy, noble metal alloys

Introduction

The marginal fit is one of the most important criteria for long-term success of all-ceramic restorations.[1] When considered clinically, a casting becomes acceptable only when the marginal gap between the prepared tooth and the casting is indiscernible both visually and also while probing. The marginal gap may lead to increased retention of plaque. This changes the distribution of microflora as the marginal gap becomes a protective space for microorganisms. This paves way for secondary caries and periodontal disease. Furthermore, microleakage under the restoration may cause endodontal inflammation and hypersensitivity.[2-4] The marginal fit of restorations is governed by many factors such as perceptive tooth preparation, accurate impressions, type of casting metal used, precision casting, and careful finishing.[3] The crowns and copings are manufactured either from base metal alloys or from noble metal alloys. The base metals commonly used are nickel chromium (NiCr) alloys. The noble metal alloys include Type III gold alloys, gold palladium, silver-palladium alloys, and alumina. When comparing NiCr and gold alloys, the former has extensive physical and mechanical properties, with greater yielding properties and moduli of elasticity.[5] The complete veneer crown is the form of crown restoration done to reproduce the normal tooth contour by artificial materials. Among the metal alloys, CoCr exhibits the best fit at the cervical and incisal areas.[6] The marginal discrepancy also varied when the NiCr crowns covered the occlusal surface and when they didn't. The marginal discrepancy was found to be higher when they covered the occlusal surface.[7] Ag Pd alloy exhibited the best marginal discrepancy when compare to Type III gold and NiCrMo alloys.[2] Hence, this systematic review was formulated with the following aims and objectives:

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Aim

The aim of this systematic review is:

- To evaluate the amount of marginal discrepancy in complete veneer crowns fabricated using base metals
- To evaluate the amount of marginal discrepancy in complete veneer crowns fabricated using noble metals
- To compare the marginal discrepancies between base metal and noble metal alloys and to infer the alloy with the least marginal discrepancy.

PICO analysis

Population

Complete cast crown, complete veneer crown, full veneer crown and metal crown.

Intervention

Base metal alloys, base metal crowns, NiCr crowns, cobalt chromium crowns and titanium crowns.

Comparison

Gold crowns, noble metal crowns, precious metal crowns, semi-precious metal crowns, Type III gold crowns, Type IV gold crowns, gold platinum crowns, and gold palladium crowns.

Outcome

Marginal discrepancy, marginal gap, marginal leakage and microleakage.

Variables of interest

Influence of the following factors on marginal discrepancy:

1. Noble metal alloys
2. Base metal alloys.

Materials and Methods

Sources used

An electronic search was initiated for scholarly articles on crowns and bridges, base metal alloys crowns, noble metal alloy crowns, and marginal discrepancy. The search was PubMed based. The search methodology applied was a combination of MESH terms and suitable keywords based on population, intervention, comparision, outcome (PICO) formulated for the review.

Search methodology

Suitable keywords were formulated for PICO and subjected to advanced search using Boolean operators.

Selection of studies

The review process comprises two phases. In the first phase, the title and abstracts of the articles obtained through PubMed search were examined for relevance. The full text of relevant articles was obtained and accessed. In the second phase, relevant articles were isolated based on inclusion and exclusion criteria, for further data extraction and statistical analysis.

Inclusion criteria

The articles focusing on the following parameters were included for the systematic review:

- *In vitro* studies evaluating marginal discrepancy in complete veneer crowns
- *In vitro* studies reporting marginal discrepancy in cast copings
- *In vitro* studies discussing the marginal discrepancy in universal post abutments.

Exclusion criteria

The articles discussing the following parameters were excluded from the systematic review:

- Case reports and case series
- Marginal discrepancy in partial veneer crowns
- Studies on inlay or onlay.

The database search yielded 17 articles of which, 6 articles were excluded after reading the abstract. For the remaining 11 articles, full text was accessed and obtained. Of these 11 articles, 6 articles were excluded based on exclusion criteria and 5 were included for the final review. The selected articles were subjected to data extraction. The following data were extracted (Charts 1 and 2):

- Journal
- Authors
- Study design
- Study groups
- Intervention/treatment
- Method of measurement
- Outcome measure - marginal discrepancy
- Statistics
- Inference.

The following data regarding marginal discrepancy were extracted from the selected articles and were tabulated as Table 1.

Name of the journal, author, the design of the study, study groups, the intervention or treatment focused in this study, methods used to measure the marginal discrepancy, outcome measure such as mean marginal discrepancy, statistical test, and inference were extracted and tabulated.

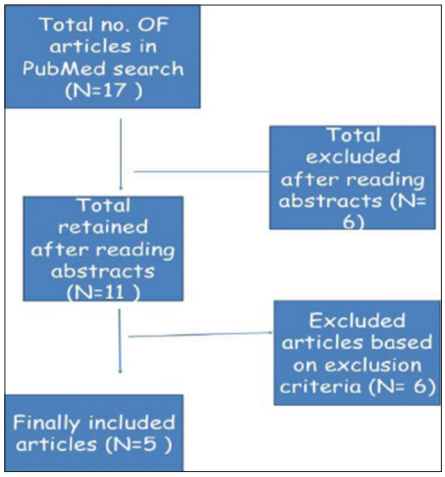

Chart 1: Flowchart for search strategy

Table 1: Marginal discrepancy data extracted from selected articles

Journal	Author	Study design	Study groups	Intervention/ treatment	Method of measurement	Outcome measure marginal discrepancy	Statistics	Inference
European Journal of Oral Sciences	Faot *et al.*, 2015	*In vitro* with paralleling group design	Cobalt chromium, nickel chromium, nickel chromium molybdenum titanium, gold and premachined alumina	Universal post abutments	Monocular microscope×20 magnification	Mean±SD in microns. CoCr - 20±10. NiCrMoTi - 15±6. NiCr - 19±10. Au - 29±11. Alumina - 105±5	One-way ANOVA, Tukeys HSD post-hoc test	The alumina group showed marginal overextension, and the Au group showed the highest discrepancy in marginal fit among the metal alloys. The CoCr and alumina groups showed the lowest discrepancies in internal fit. In conclusion, the alumina cylinders exhibited the best internal fit, despite their horizontal overextension. Among the metal alloys, CoCr exhibited the best fit at critical regions, such as the cervical and occlusal areas
European Journal of Prosthodontics and Restorative Dentistry	Regish *et al.*, 2013	*In vitro* with paralleling group design	NiCr and zirconia copings, Group 1 - NiCr copings fabricated using lost wax technique, Group 2 - NiCr copings fabricated using lost wax technique and veneered with ceramic, Group 3 - Zirconia copings fabricated using copy milling, Group 4 - Zirconia copings fabricated using copy milling and veneered with ceramic	Base metal and zirconia copings	SEM	In microns. Mean±SD 1-204.48±46.99, 2-205.24±51.76, 3-274.80±20.35, 4-238.34±55.67	Student's *t*-test	The internal fit and marginal adaptability of NiCr copings were found to be better than copy milled Zirconia copings but internal fit and marginal adaptability deteriorated after ceramic veneering
Journal of Prosthodontics	Saber *et al.*, 2013	*In vitro* with paralleling group design	NiCr based metal ceramic alloy Group 1 - Dies were covered with 4 layers of die spacer, covering the entire preparation together with occlusal surface excluding apical 0.5 mm of preparation. Group 2 - Covering same area excluding the occlusal surface	Crowns, metal ceramic copings	Stereoscopic zoom microscope at×20 magnification	In microns. Mean±SD Group 1-103.16±44.33. Group 2-77.16±35.5	Student's *t*-test	The marginal discrepancies of Group 1 were higher than those of Group 2
The Journal of Prosthetic Dentistry	Tjan *et al.*, 1991	*In vitro* with paralleling group design	1 low gold palladium alloy, 1 high palladium alloy, 1 silver palladium alloy, 1 nickel chromium molybdenum base alloy, 1 copper aluminium base alloy and Type III high gold alloy	Complete crowns	Steromicroscope at×4 magnification, video microscope with digimatic micrometers	Mean±SD in microns. Harmony line - 9.7±3.59. W3-43.0±13.51. Spirit 2 plus - 45.8±12.07. Duracast MS - 45.2±15.02. Litecast - 121.1±21.50. Elektra - 22.2±3.74	One-way ANOVA, Duncan's multiple range test	The findings indicated that Ag-Pd alloy crowns exhibited the best marginal accuracy among the alternative alloys tested. However, their marginal discrepancy value was still slightly higher than that of crowns made of type III high-gold alloy. Conversely, NiCr-Mo alloy crowns exhibited the poorest marginal accuracy
Journal of Prosthetic Dentistry	Duncan, 1982	*In vitro* with paralleling group design	NiCr alloys (Ultratek, Nobil cream, Microbond, Omega). Ceramic precious casting alloy (Jelenko O)	Cast copings for maxillary central incisor	Stereo microscope Bausch n Lomb×20	Jelenko O - Mean±SD - 0.111±0.0832. Ultratek - 0.237±0.09776. Omega - 0.463±0.2297. Micro bond - 0.451±0.1933. Nobil cream - 0.373±0.0816	Duncan's new multiple range test	Least discrepancy in Jelenko alloy (ceramic precious casting alloy)

NiCr: Nickel chromium, SEM: Scanning electron microscope

#40	Add	Search (((Marginal discrepancy) OR Marginal gap) OR Marginal leakage) OR Microleakage	4804	05:21:40
#39	Add	Search Microleakage	2651	05:21:03
#38	Add	Search Marginal leakage	1584	05:20:55
#37	Add	Search Marginal gap	1183	05:20:44
#13	Add	Search Marginal discrepancy	390	05:20:29
#36	Add	Search (((((((Gold crowns) OR Noble metal crowns) OR Precious metal crowns) OR Semi precious metal crowns) OR Type III gold crowns) OR Type IV gold crowns) OR Gold platinum crowns) OR Gold palladium crowns	1553	05:18:58
#35	Add	Search Gold palladium crowns	131	05:18:19
#34	Add	Search Gold platinum crowns	45	05:18:07
#33	Add	Search Type IV gold crowns	23	05:17:46
#32	Add	Search Type III gold crowns	38	05:17:28
#31	Add	Search Semi precious metal crowns	5	05:17:06
#30	Add	Search Precious metal crowns	147	05:16:54
#29	Add	Search Noble metal crowns	94	05:16:40
#28	Add	Search Gold crowns	1426	05:16:28
#27	Add	Search (((Base metal alloy crowns) OR Nickel chromium crowns) OR Titanium crowns) OR Cobalt chromium crowns	1324	05:16:11
#26	Add	Search Titanium crowns	950	05:14:37
#25	Add	Search Cobalt chromium crowns	97	05:14:27
#24	Add	Search Nickel chromium crowns	173	05:14:14
#23	Add	Search Base metal alloy crowns	216	05:13:51
#11	Add	Search Base metal alloys	1913	05:13:38
#22	Add	Search (((Complete cast crown) OR Complete veneer crown) OR Full veneer crown) OR Metal crown	8132	05:12:31
#21	Add	Search Metal crown	7953	05:12:07
#20	Add	Search Full veneer crown	122	05:11:59
#19	Add	Search Complete veneer crown	76	05:11:49
#18	Add	Search Complete cast crown	191	05:11:33

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Search	Add to builder	Query	Items found	Time
#41	Add	Search (((((((Complete cast crown) OR Complete veneer crown) OR Full veneer crown) OR Metal crown)) AND ((((Base metal alloy crowns) OR Nickel chromium crowns) OR Titanium crowns) OR Cobalt chromium crowns)) AND (((((((Gold crowns) OR Noble metal crowns) OR Precious metal crowns) OR Semi precious metal crowns) OR Type III gold crowns) OR Type IV gold crowns) OR Gold platinum crowns) OR Gold palladium crowns)) AND ((((Marginal discrepancy) OR Marginal gap) OR Marginal leakage) OR Microleakage)	17	05:22:29
#40	Add	Search (((Marginal discrepancy) OR Marginal gap) OR Marginal leakage) OR Microleakage	4804	05:21:40
#39	Add	Search Microleakage	2651	05:21:03
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#37	Add	Search Marginal gap	1183	05:20:44
#13	Add	Search Marginal discrepancy	390	05:20:29
#36	Add	Search (((((((Gold crowns) OR Noble metal crowns) OR Precious metal crowns) OR Semi precious metal crowns) OR Type III gold crowns) OR Type IV gold crowns)	1553	05:18:58

b

Chart 2: (a and b) PubMed search

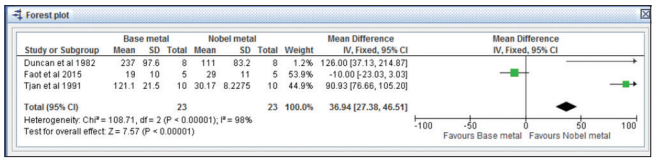

Figure 1: Forest plot and meta analysis

Results

The following information was extracted and tabulated. Name of the journal, author, the design of the study, study groups, the intervention or treatment focused in this study, methods used to measure the marginal discrepancy, outcome measure such as mean marginal discrepancy, statistical test, and inference were extracted and tabulated (Table 1). 5 studies were included for the review. All the 5 studies included for the systematic review were *in vitro* studies with paralleling group design. The base metal alloy and noble metal alloy studied differed in the chosen studies. However, NiCr was the common base metal alloy among all the five studies. Rejish *et al*. studied the internal fit of NiCr and zirconia copings before and after ceramic veneering rather than the comparison between base metal and noble metal alloys (Table 1). Saber *et al*. evaluated the marginal discrepancy only in NiCr base metal-ceramic alloy crowns as two groups - covering the entire preparation including occlusal surface and excluding occlusal surface (Table 1). Hence, these studies cannot be included for meta analysis. The studies of Faot *et al*., Tjan *et al*., and Duncan, which compared the marginal discrepancy between base metal and noble metal alloys were subjected to meta analysis (Table 1). The effect size parameter for this meta analysis was the difference between the means in base metal and noble metal alloys, respectively. The results showed a marked deviation toward noble metal in a forest plot (Figure 1). The heterogeneity of variance was observed in the selected studies Chi-square = 108.71, df = 2 ($P < 0.00001$), $I^2 = 98\%$; and hence a fixed effects model was chosen. The overall effect size was $Z = 7.57$ ($P < 0.00001$). Hence, a very significant difference in the marginal discrepancy between base metal alloy and noble metal alloys was inferred.

Discussion

Literature includes more number of *in vitro* studies than *in vivo* studies with respect to marginal discrepancy in complete veneer crowns. The limitation of *in vitro* studies is that they are conducted in laboratory conditions, but further *in vivo* studies must be carried out to check if the same results are obtained.[8]

All the five studies selected for the review process were *in vitro* studies with paralleling group design. The method of measurement of marginal discrepancy was predominantly stereomicroscope (different magnifications) (Saber *et al*., Tjan *et al*., Duncan). Other methods used were monocular magnification (Faot *et al*.) and scanning electron microscope (Regish *et al*.). The study groups varied with each study designed with its own group of base metal and noble metal alloys.

Faot *et al*. (Table 1) have used only one base metal alloy – NiCr while the noble metal alloys used were CoCr, NiCrMo, Au, and Alumina. Of these base metals, we chose Au for the meta Analysis against NiCr because Au had incurred the highest marginal discrepancy (29 ± 11) among all other noble metal alloys used in this study. In relation to this, other studies have also reported that the rising cost of gold has encouraged the search for alternative dental alloys[2] of which NiCr alloys have received much attention.[9,10]

Regish *et al*. (Table 1) used NiCr and zirconia copings. However, his study primarily focused on the marginal discrepancy before and after ceramic veneering rather than on the marginal discrepancy based on the type of alloy used. The zirconia copings are typically manufactured using manual-aided manufacturing/computer-aided manufacturing (CAM) or computer-aided design/CAM. Also according to a study, the vertical marginal discrepancy of zirconia restorations was smaller than that of metal ceramic group. Copy milling is another technique employed in all ceramic fabrication. This technique is employed in celay system that is commercially used. Here, a resin wax pattern is fabricated over the refractory die and laser scan is used which subsequently transfers the scanned image and a ceramic core is fabricated.[1] However, for both the alloy systems, it was found that the marginal fit deteriorated after ceramic veneering. As there was not any significant analysis of marginal discrepancy based on the alloy system, this study was excluded from meta analysis. Similarly, the study of Saber *et al*., which had used only NiCr alloys, was also excluded from meta analysis (Table 1).

A meta analysis was possible for the assessment of marginal discrepancy in base metal alloys and noble metal alloys used in the studies by Duncan, Faot *et al*., and Tjan *et al*. The effect size for this meta analysis was the difference between the means in base metal alloys and noble metal alloy, respectively. The results showed a significant deviation toward the noble metals group in the forest plot favoring the noble metal group with less marginal discrepancy in all the studies. This strongly indicates that the type of alloy and the alloy composition have a significant effect on marginal discrepancy.[11] While selecting an alloy, the factors to be taken into consideration include castability, alloy casting accuracy, resistance to tarnish, and corrosion and biocompatibility. It has been reported that decrease in noble metal content decrease the resistance to tarnish and corrosion.[2,11,12] Moreover, NiCr alloys containing beryllium had improved casting accuracy, lower casting temperature, and less casting shrinkage. Thus, further studies with controlled variables need to be initiated and such quantitative outcome measures will enable further understanding and could be a scope for future research.

This systematic review thus reveals that the base metal alloys incurred more marginal discrepancy when compared with noble metal alloys. However, the marginal discrepancy incurred is considered clinically acceptable.

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