Effect of Recasted Base Metal Alloys on Surface Roughness for Dental Prosthesis – A Meta-Analysis

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Abstract

Background: For dental applications base metal alloys stands on top of hierarchical preferences however, the cost of previously used alloys has significantly amplified, making it advantageous from economic standpoint to combine recycled alloy with new alloy to lower the price of fixed partial dentures. The purpose of the meta-analysis is to evaluate the surface roughness during the fabrication of dental prosthesis by recasted alloys. **Objective:** This study assessed the influence of recasting on the surface roughness of base metal alloys. **Data Source:** Following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis protocol, this study was intended with the following question: "Is the surface roughness of dental alloys affected by recycle recasted alloy?". The inclusion criteria comprised *in vitro* studies that measured the surface roughness of 100% recasted alloys. The database search involved articles published from 2013 to 2023 on PubMed/MEDLINE, Web of Science, Google Scholar, and Scopus using the following keywords: Surface roughness maximum, surface roughness average, base metal alloys, and recasted alloy. **Results:** The data base search resulted scarce published pool of 115 articles beholding the screening mechanism where duplicated and similar studies were excluded from the study. Subsequently, 19 eligible trials considering surface roughness of recycled recasted alloy and new alloy were equally randomized for intervention. Therefore, there were barely *in vitro* study trials on fully recasted recycled alloy employed for dental prosthetic use. **Conclusion:** Results of primary research question in the present systematic review and meta-analysis as compared to the fresh alloys showed that the recasted alloys have increased surface roughness resulting in inferior mechanical properties.

Keywords: Surface roughness, Recasting, Base metal alloys.

Introduction

The recasting of dental alloys has a long history in dentistry when gold alloys were first used in dental restorations. Recasting involves melting down used dental restorations and reusing the metal to create new dental prosthetics, offering both economic and environmental benefits. However, the effect of recasting on the surface roughness of base metal alloys has been a topic of interest and concern in recent years.[1-3]

The surface roughness of dental prosthetics can have a significant impact on their performance and longevity. Rough surfaces can increase the risk of plaque accumulation, bacterial adhesion, and mechanical wear, leading to discomfort, infection, and failure of the dental restoration. The recasting of dental alloys can potentially lead to an increase in surface roughness due to the formation of defects and imperfections during the melting and casting process.[4-6]

Meta-analysis is a statistical technique that examines the findings from retrospective published literature to answer a specific research issue. In the case of the effect of recycling re-casted alloy on the surface roughness of base metal alloys, a meta-analysis can provide a comprehensive overview on mechanical properties compromised during recycling and its impact on recycled alloys.[7-9] This includes evaluating the methods used in previous studies, the types of alloys used in fabrication of dental prosthesis, and the specific effects observed on surface roughness its cost effectiveness, durability, quality assurance, luster, and its perspective on oral health.[10,11]

Aiming at the mechanical effect of recycling and recasting on the surface roughness of base metal alloys, it can provide

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a review of the available evidence and to determine the overall level of risk associated with this practice.[12,13] This information can be used to inform clinical decision-making when considering the use of recasted dental alloys in dental restorations with a focus on minimizing surface roughness and ensuring the longevity and efficacy of the dental prosthetic.[14,15] By providing a comprehensive overview of the available literature, a meta-analysis can help to inform clinical decision-making and promote safe and effective dental restorations and the futuristic innovative way to enhance the mechanical properties.[16-19]

Materials and Methods

Focused question and study protocol

The study protocol was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model.[20-23] The focused question of this systematic review was formulated following the PICOS model to lead the literature search as follows: Population (P): Fresh alloy (Ni-Cr or Co-Cr); Intervention (I): Recasting; Comparison (C) Recasted alloy (Ni-Cr or Co-Cr); Outcomes (O): Surface roughness; and Study design (S): Non-randomized controlled clinical trials (nRCTs). After these elements were analyzed, the investigated PICOS question was as follows: ''Is the surface roughness of dental alloys affected by recycle re-casted alloy?''

Eligibility criteria

Inclusion criteria

The following criteria were included in the study:

1. Fulltext articles published solely in the English language.
2. *In vitro* non-randomized control trial studies having comparison for surface roughness between fresh and 100% recasted alloys.

Exclusion criteria

The following criteria were excluded from the study:

1. It was an *in vivo* study
2. The study was published other than the English language
3. Animal studies
4. Studies done on exclusively single population (either fresh or recasted alloy).

Search strategy

The search strategy through various electronic databases, appropriate literature on availability through these search engines (MEDLINE/PubMed/Web of Science, the Cochrane Register of Randomized Controlled Trials, and the Database of Abstracts of Reviews of Effects) included in the current systematic review and meta-analysis. The Cochrane Central Register of Controlled Trials,[24,25] Science Direct, and Google Scholar were conducted using the MESH terminologies "recasted alloy," "fresh alloy," and "surface roughness."

Study screening, selection, and management

As the data extracted and retrieved for synthesis in the systematic review and meta-analysis were employed by the Cochrane data collection form for intervention reviews for preliminary screening. Base metal alloys, recasted alloys, recycled alloy, and related surface roughness were the variables evaluated for data extraction. The percentage of recycled base metal alloys used was additional data gleaned from the included studies. One hundred and fifteen articles were included in the screening mechanism, all duplicated similar studies were excluded from the study. Subsequently, 19 eligible articles published as randomized or non-randomized trials considering surface roughness of recasted alloy and new alloy were eligible as per the guidelines. To fix the duration, only past 10 years published articles to compare the surface roughness of fresh and recycles recasted alloy as interventional studies also constricted the parameters. Reportedly, only three published articles fulfilling the selection criteria as per the inclusion and exclusions laid in the extraction of literature were subjected for synthesis for systematic review and meta-analysis.

Strategy of data synthesis

The purpose of systematic review and meta-analyses was performed utilizing comparable interventions, comparisons, and results from the non-randomized trials. The data synthesis is a systematic approach to combining and analyzing data from multiple sources to generate meaningful insights from various data sources to create a comprehensive view. Common approaches including aggregating, merging, and transforming data followed by data analysis. The choice of strategy depends on the specific goals and characteristic of the data to create a cohesive and informative representation of the data.

Risk of bias evaluation

The MINORS tool was used to assess the methodological quality of non-randomized studies.[26] The tool assessed the studies' reliability and randomization. Eleven domains were used to evaluate the risk of bias: (1) A clearly stated goal, (2) a digital technique for assessing surface roughness, (3) a validation of sample size, (4) randomization of samples, (5) an explanation of how the recasted alloy was made, (6) the test group material, (7) measurement of standardization, (8) measurement method, (8) measurement reproducibility, (9) adequate statistical analysis, (10) adequate statistical analysis, and (11) overall evaluation (Table 1).

The modified methodological index for non-randomized studies (MINORS) was used to investigate the methodology of the quality assessment of the included studies. There will be a 20-point maximum likely score for each study. The present analysis's included studies were of high quality, which decreased the likelihood of bias.

Statistical analysis

Through meta-analysis, the comparison of the surface roughness of freshly casted and recycled recast alloys using multiple independent studies on the same topic to draw more robust conclusion. Calculating the mean difference with a 95% confidence interval, significance was set at

Table 1: Risk of bias evaluation by MINORS tool

Checklist	Agrawal *et al.*[27]	Shrivastava *et al.*[28]	Das[29]
Clearly stated aim	2	2	2
Digital method of measuring cytotoxicity	2	2	2
Validation of sample size	2	2	2
Sample randomization	2	2	2
Description of fabrication of recasted alloy	2	2	2
Test group material	2	2	2
Measurement of standardization	2	2	2
Measurement method	2	2	2
Measurement reproducibility	2	2	2
Adequate statistical analysis	2	2	2
Overall appraisal	Include	Include	Include

0: Not reported; 1: Inadequately reported; 2: Adequately reported

$P = 0.05$. To determine the significance of the difference between the two group's results, P value was used. Surface roughness of newly cast alloys and previously cast alloys was statistically different if P 0.05. Review Manager (RevMan), the 5.4 version, the Cochrane Collaboration, 2020, Copenhagen: The Nordic Cochrane Centre, Denmark (Computer Programme) was used to examine these effects and make a forest plan. Research on several geographical regions was used to gather data. Heterogeneity for this analysis was 0% suggesting no variability between the studies included.

Results

The primarily search throughout the four scientific databases yielded 115 scientific publications (Figure 1). Among them, 68 were duplicates, 17 were ineligible, and five were not published in English and, thus, were excluded from the study. A total of 19 scientific papers were extensively scrutinized for abstract review, and four were found to be related to this review question. After scrutinizing these articles, three fulfilled the inclusion criteria and were added in the data analysis. Table 2 lists the data features for each study.

Qualitative data analysis

The studies included different proportion of recasting done; however, in this meta-analysis, only 100% recasted alloys were analyzed. Three studies were assessed for surface roughness between fresh and recasted alloys. A total of 155 samples as population were examined in these three studies. When compared against 100% recasted alloy, a significant difference was noted between the two groups at $P = 0.06$ A mean difference of 4.71 was noted with 95% CI, with recasted alloys having greater surface roughness than recasted metal (Figure 2). Review Manager 5.4 was used for analysis of data. For the statistical outcome, all results were shown in a forest plot based on standardized mean differences with a fixed-effects model to respect heterogeneity of these studies. To assess the heterogeneity of the different trials, I^2-value was performed.[30]

Discussion

The primary goal of this meta-analysis was to gather and compile data from published sources about the surface roughness of recast alloys. Various studies included different methods to check the changes in the surface roughness of base metal alloys. The study conducted by Bezzon *et al.*[31] was to assess the surface roughness of two base metal alloys, undergoing different casting techniques, to determine the influence of surface roughness on loss of mass after polishing compared to commercially pure titanium castings. Castillo-Oyagüe *et al.*[32] conducted a study to evaluate the effect of four chemomechanical surface treatments, that is, sandblasting; 125 µm Al_2O_3-particles; silica coating 50 µm silica-modified Al_2O_3-particles; oxidation; and oxidation plus opacification on the surface average microroughness and profile of laser-sintered and vacuum-cast dental prosthetic structures. The study by Zhu *et al.*[33] aims to explore the effect of the electrical discharge machining parameters and TiC powder concentration on the machining properties and surface characteristics of the TiNi SMA. It was found that the material removal rate (MRR), surface roughness, and thickness of the recast layer increased with an increase in the discharge energy.[34-37] However, these studies did not fall into the inclusion criteria. Similarly, articles which did not match the methodology or the time frame considered or the percentage of recasting were not considered in this review. There were main three studies included in this meta-analysis.[38-40] The research by Agrawal *et al.*[27] indicated that the surface roughness differences between the new alloy and the recast alloy were statistically significant. The surface roughness tester was installed with samples for the purpose of evaluating surface roughness, maximum surface roughness readings were obtained by a digital meter using a diamond stylus that travels through a predetermined distance on the surface roughness tester. According to Shrivastava *et al.*,[28] surface roughness rises as the proportion of recast alloy utilized in the casting preparation process. The minimum is new alloy, followed by 25% recast alloy, 50% recast alloy, and 100% recast alloy as the highest. They carried out a study, separated the alloys into 4 groups, and used a tester

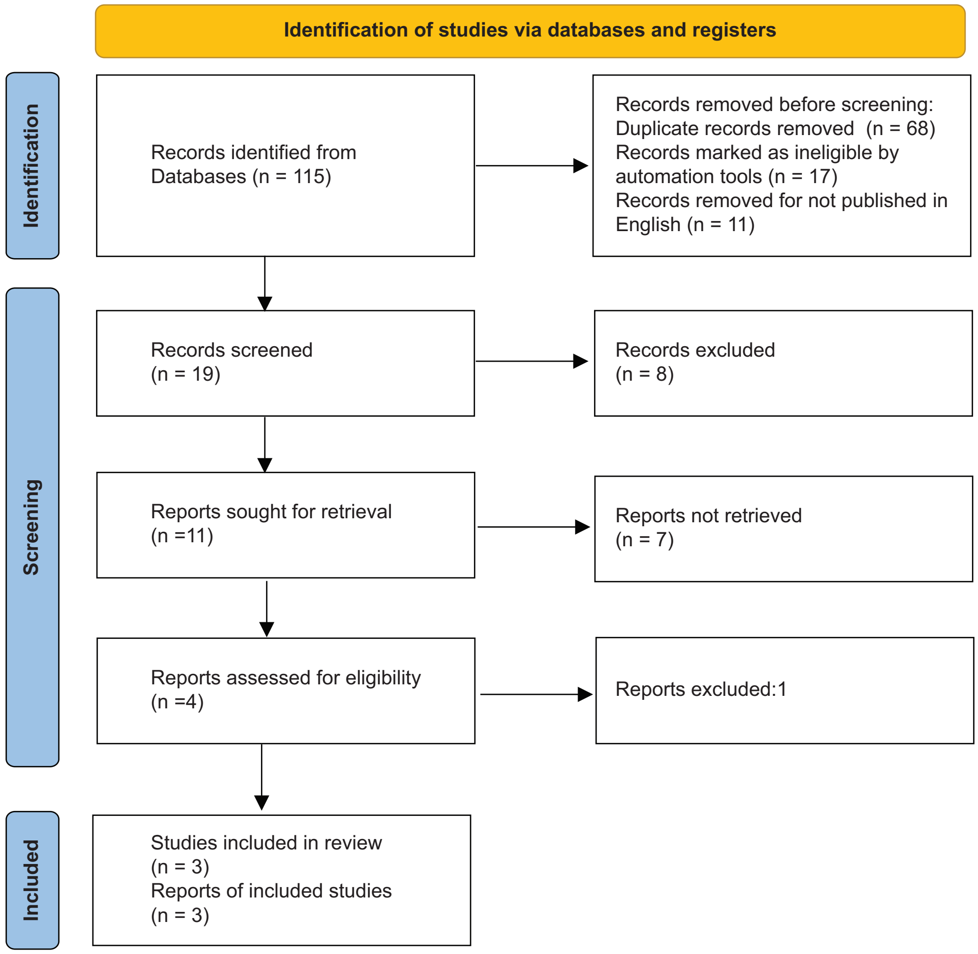

Figure 1: Identification of studies through databases and registers

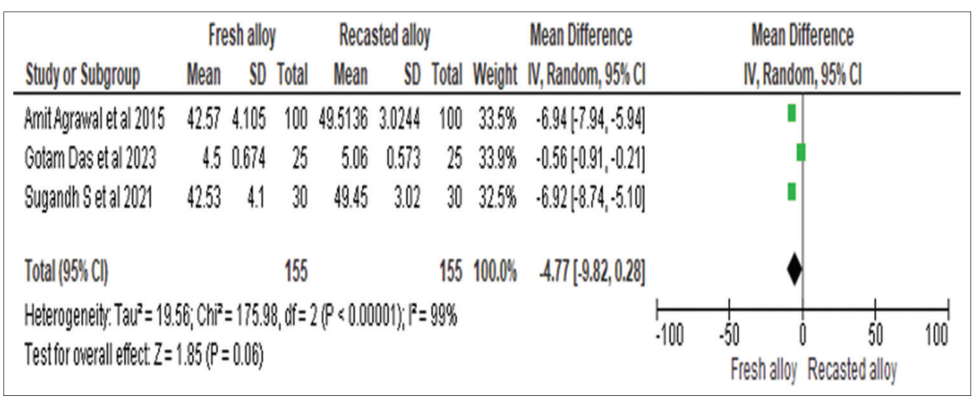

Figure 2: Forest plot depicting comparison of surface roughness between recasted and fresh alloy

to measure surface roughness[3,41,42]. According to Das,[29] the outer surface of all castings had different degrees of surface roughness, which affects the physical behavior of the casted metal. It showed that changes in surface roughness were minimal at 4.5 ± 0.67 µm for castings with the new alloy, while compared to the recast alloy with 25% old at 4.61 ± 0.67 µm, 50% old at 5.06 ± 0.57 µm, 75% old at 5.32 ± 0.70 µm, and 100% old at 5.52 ± 0.71 µm. Changes in surface roughness in new or recast were increasing with the increase in percent of recasting.[43-46] These studies suggest that the creation of oxide layers, incorporation of oxygen and nitrogen, loss of specific trace elements including manganese, chromium, and molybdenum, and compositional changes are the main reasons of surface roughness.[47]

Conclusion

A network meta-analysis including only non-randomized controlled trials was included to assess and compare difference in surface roughness of base metal alloys for rehabilitation of oral

Table 2: Features of the study

Author	Year	Study design	Study group	Outcome parameters	Intervention	Results
Agrawal *et al*.	Journal of Clinical and Diagnostic Research. 2015	*In vitro* three-way ANOVA	A total of 200 test specimens were fabricated divided into two groups - 100 specimens of new alloy and 100 specimens of recast alloys, which were tested for tensile strength on universal testing machine and surface roughness on surface roughness tester	Surface roughness of recast base metal alloys at different percentages	Surface roughness of recasted alloys	Within the limitations of the study, it is concluded that the tensile strength will not be affected by recasting of nickel chromium alloy whereas surface roughness increases markedly
Shrivastava *et al*.	People's Journal of Scientific Research July 2021	*In vitro* comparative study	Fresh and once-recast nickel-chromium alloys were employed in varying ratios and separated into 5 groups, with 10 specimens each in Group A, B, C, D, and E, which used 100%, 75%, 50%, 25%, and 0% of fresh alloy, respectively	Surface roughness of recast base metal alloys at different percentages	Surface roughness of recasted alloys	Recasting a nickel-chromium alloy does not change its tensile strength, but it does result in a significant increase in surface roughness
Das		*In vitro* comparative study	Recast Ni-Cr alloy were divided into five groups, each containing 25 crowns. Group A: 100% new alloy (control) Group B: 75% new alloy and 25% recast alloy Group C: 50% new alloy and 50% recast alloy Group D: 25% new alloy and 75% recast alloy Group E: 100% recast alloy	Surface roughness of recast base metal alloys at different percentages	Surface roughness of recasted alloys	Changes in surface roughness in new or recast were increasing with the increase in percent of recasting

structures. Extracted articles were arranged and classified based on the inclusive criteria. According to these studies findings, when compared to recast alloy, the surface roughness of the new alloy was found to be increased. Therefore, the fresh alloys should be used for the fabrication of dental prosthesis, as the recasted alloys have increased surface roughness resulting in the reduction of the properties. Hence, however, cost effectiveness is present in case of recasting but the results compromised in such cases will also have to be addressed. The increase in surface roughness along with other mechanical properties ultimately results in the reduction of the quality of the metal being used for the fabrication of dental prosthesis. Once again due to financial concern, making it advantageous from all standards and economic standpoint to combine recycled alloy with new alloy or total recycling of the alloy reduces the quality in manifold as longevity and durability. However, the large void in the research field needs to be fulfilled as futuristic approach in fabrication of quality dental applications.

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Conflicts of interest

There are no conflicts of interest.

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