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Research Article

EFFECT OF ADDING RECAST NICKEL-CHROMIUM ALLOY IN DIFFERENT PERCENTAGE WEIGHT TO FRESH ALLOY ON THE MARGINAL ACCURACY OF COMPLETE CAST CROWNS: AN IN VITRO STUDY

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ABSTRACT

Background and Objectives: Failure of extra coronal restorations from secondary caries and periodontal problems are quite common. Intact marginal adaptation or marginal accuracy is essential to prevent oral fluid entry in between the restoration and abutment tooth causing luting cement dissolution and failure of the restoration. Even though manufacturers advice single use of base metal casting alloys; due to the increased demand and economy, reusing of cast alloy is practiced by many dental laboratories.

Materials and Method: A master die was fabricated in brass and a wax pattern for complete cast crown was carved over it. These patterns was duplicated to fabricate 72 identical wax samples using a custom made duplicating mold and were randomly distributed into six groups (A to F). These groups were then cast with different percentage of new and once cast alloy. The cast crowns were held in position over the master die with the help of a custom made holding device and each surface was examined for marginal gap under a stereomicroscope. The marginal gap values were recorded in microns and subjected to statistical analysis using One way ANOVA, Independent samples 't' test and Scheffe's post hoc test.

Results: The mean marginal gap values obtained for groups A, B, C, D, E and F were 48.55μ, 49.12μ, 61.63μ, 63.97μ, 67.77μ and 70.34μ respectively. Significant difference was observed between the groups.

Conclusion: Increase in mean marginal gap was observed with increase in the amount of once cast alloy, but these values were within the clinically acceptable range. Intergroup comparisons showed statistically highly significant difference in marginal gap in an ascending order from group A to group F. No statistical difference was observed among the four surfaces of same sample of any test groups.

INTRODUCTION

Tooth loss affects the function and esthetics either directly by the loss of tooth itself or indirectly by the effect on surrounding structures. As these negative changes of the oral biomechanics portray negativism on the persons themselves, they should be treated not only for the replacement of oral structure but for complete rehabilitation of individual identity.

The successful integration of esthetics and function in a fixed prosthesis do not emerge by chance, but rather as a result of the meticulous development of clearly defined parameters and their subsequent incorporation into the design of the prosthesis. Fixed prosthesis can transform an unhealthy, unattractive dentition with poor function into a comfortable, healthy occlusion capable of giving years of service while greatly enhancing esthetics.[1] Metallic framework for fixed prosthesis is usually fabricated by the lost wax technique (Investment casting). This technique became the most significant advancement in restorative dentistry since its introduction in 1907 by Dr. William Taggart.[2]

Success of a fixed prosthesis is depended on various mechanical and biological principles. The most important being the margin of the preparation and the marginal fit of fabricated prosthesis. Any ill fitting margins can cause accumulation of plaque around the margins inviting periodontal problems, dissolution of the luting cement giving way for saliva and oral microbes to penetrate into the prepared tooth surface causing formation of secondary caries, loss of retention etc.

Earlier, cast gold alloys were considered to be the standard material of choice for crown and bridge dentistry. Their properties like resistance to tarnish and corrosion, hardness, strength, percentage elongation, castability, burnishability and capacity to take high polish made them ideal crown and bridge

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material. However, two main disadvantages of gold alloys were colour and high cost. Eardle RW and Prange CH introduced base metal alloys to dentistry in 1930's which became popular, as their properties were in par with that of gold alloys and had the additional advantage of reduced gravity and low cost.[3] Even though manufacturers advice single use of these base metal alloys, the present high demand for these alloys and the depleting level of natural resources have resulted in the increased price of these once insignificant alloys. It will be of great help both economically and environmentally to recycle and reuse the alloys more than once. Many laboratories combine new alloy with used alloy in various percentages.

There are numerous studies carried out to study the repeated usage of precious metals and their physical properties such as hardness, strength, percentage elongation, castability, burnishability etc.[4-7] But fewer studies have been done on evaluating the effect of recycling and reusing base metal alloys. Changes occurring in the properties of these alloys due to reuse can jeopardize the whole idea of giving a successful long term fixed prosthesis. The present study was performed to evaluate the effect of adding recast Nickel-Chromium (Ni-Cr) alloy in different percentage by weight to new or fresh Ni-Cr alloy, on the marginal accuracy of complete cast crowns.

MATERIALS & METHOD

One artificial typhodont maxillary right first molar (Nissin, Japan) was mounted on its respective acrylic jaw model for tooth preparation to receive full cast crown, with 1 mm uniform chamfer finish line and six degrees overall taper (Fig.1). An impression of the prepared tooth was made using putty-reline technique using additional polyvinylsiloxane (PVS) material (Flexceed, GC, Japan).

Figure 1 Prepared typhodont tooth

Type- II inlay wax (Renfert, Germany) was melt and poured into this impression. The wax replica was carefully teased out of the impression, once it was cool and set (Fig.2). This wax replica was sprued and then invested using phosphate bonded investment material (Bellasun, Bego, Germany), followed by conventional burnout procedure and the casting was done in an electrical induction casting machine (Fornax, Bego, Germany), with brass alloy to form the master die (Fig.3).

Fig 2 Wax replica of prepared typhodont tooth

Fig 3 Brass master die

This master die was mounted in chemically cured acrylic resin (RR Cold Cure, DPI, India) block of dimensions 3x3cm, till a level, 1.5mm below the prepared tooth margin and was then embedded in dental stone (Gemstone, Shruti, India) block of dimensions 4x4cm, forming a casing around the resin block, up to a level 3mm below the acrylic margin which formed the die assembly (Fig.4). Wax pattern for a full metal crown was carved over the die (Fig.5) using Type-II inlay wax.

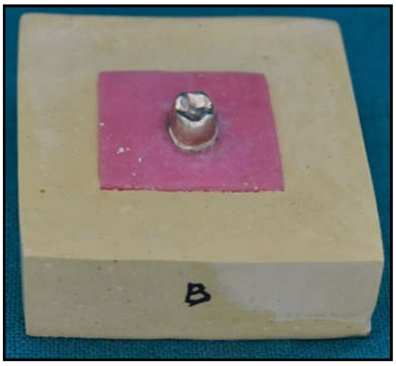

Fig 4 Die assembly

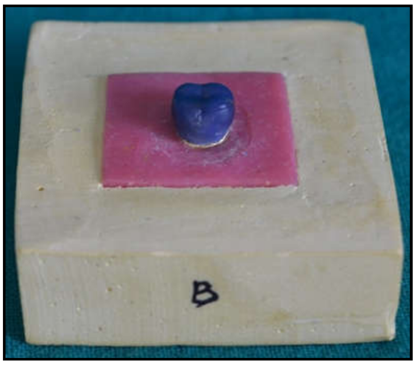

Fig 5 Wax pattern carved over master die

Boxing was done around the acrylic block to a level of 1cm above the carved wax pattern and was filled with PVS light body impression material by injection method (Fig.6). Another box was created around the dental stone casing and was filled with Type- IV die stone (Kalrock, Kalabhai, India) forming a casing around the light body impression material. This assembly acted as a mold for duplicating identical wax patterns for the study, directly over the master die (Fig.7).[8,9]

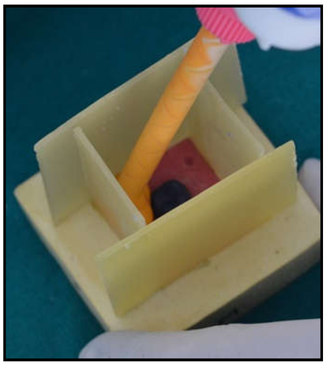

Fig 6 Boxing around wax pattern and injection of PVS light body

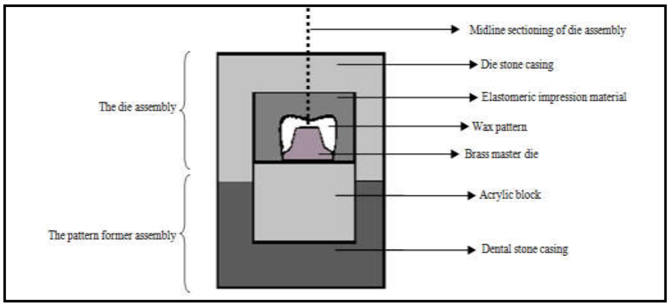

Fig 7 Diagrammatic illustration of die assembly- pattern former for fabricating the wax patterns

After separation, the pattern former was sectioned in the center in a mesio- distal direction which made the removal of the duplicated patterns easier (Fig.8).

Fig 8 Separated die assembly- pattern former

Both the halves of the pattern former assembly were held together, to which Type- II inlay wax was melt and poured. This assembly was placed over the die assembly and held in position till the wax cooled completely. The wax patterns were recovered by separating the two halves. Patterns were inspected for any defects and completeness. Minor corrections, if any were done using hand instruments. The patterns with any major defects were discarded. 72 satisfactory wax samples were fabricated for the study purpose (Fig. 9).

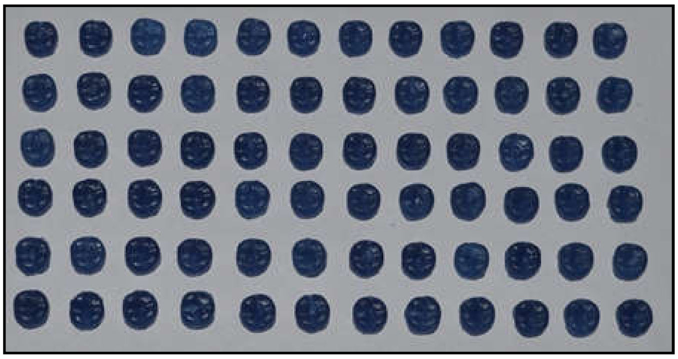

Fig 9 Duplicated identical wax patterns

All the 72 samples were randomly distrinuted into six groups with 12 samples in each group. New and once cast Ni- Cr dental alloy (Bellabond plus, Bego, Germany) was used in varying percentage combination by weight for casting of different groups as per Table 1. The wax samples of each group were sprued using gate technique.[10] The wax patterns and attached spures were measured using a electronic weighing unit. The amount of alloy required for casting was calculated using the formula-

Table 1 Grouping of samples

Groups	New ni-cr alloy (by weight)	Once cast ni-cr alloy (by weight)
Group A (Control group)	100%	0%
Group B	75%	25%
Group C	50%	50%
Group D	25%	75%
Group E	0%	100%
Group F	0%	100% (Second generation recasting)

$$\text{Weight of alloy required for casting} = \frac{\text{Weight of wax pattern} \times \text{Density of alloy}}{1.05}$$

Each group was invested using phosphate bonded material following manufacturer's instructions and casting was completed. Following retrieval of cast samples, sandblasting was done with aluminum oxide (80µ) for 10 seconds from a distance of 2 cm, at 2 bar pressure and at 45 degrees approximate angulation and were inspected for any defects. These castings were then trimmed, finished and polished in a conventional manner (Fig. 10). Extreme care was taken during all this procedures, not to disturb the margins of the fabricated metal crown samples.

All the cast crown samples from different groups were stored in separate labeled containers. The brass master die was removed from the die assembly and a smaller flat base of 2x2cm of chemically cured acrylic resin was fabricated for holding it under microscope. The samples were individually secured on the master die with the help of a specially designed holding device (Fig.11) and where then examined for marginal gap under a stereomicroscope[11,12] (Fig.11), measured at 50x optical zoom. The marginal discrepancies of the cast crowns were determined by measuring the space between the margins of the cast crown and the finish line of the master die using Clemex software (Fig. 12). On each four surfaces (Mesial, Distal, Buccal and Palatal) of the master die- crown assembly, five random points were selected and the gap between the crown margin and margin of finish line on the die were measured in microns (µ). The average of these five readings on each surface was taken as the reading for that particular surface and the average reading of all the four surfaces was taken as the value for individual metal crown sample. Values for each specimen were noted down on a master chart. These observed values were then subjected to statistical analysis using one way ANOVA, independent samples *t* test and Scheffe's post hoc test.

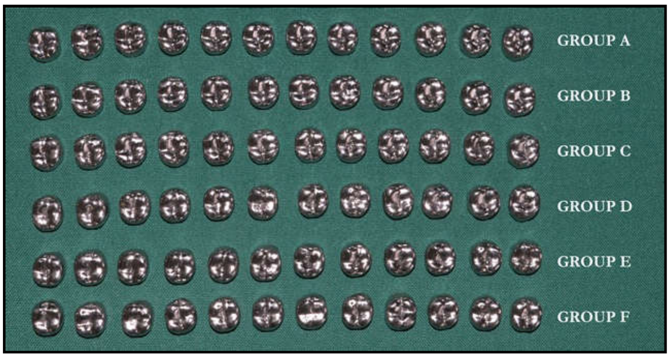

Fig 10 Ni- Cr cast crown samples (Group A – Group F) ready for testing the marginal gap

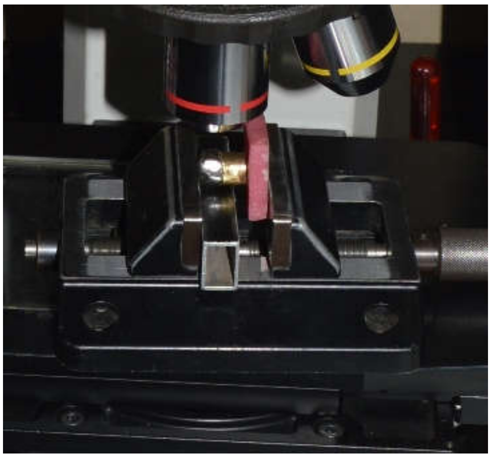

Fig 11 Cast crown positioned on the brass die using the holding device, observed under stereomicroscope for marginal gap evaluation

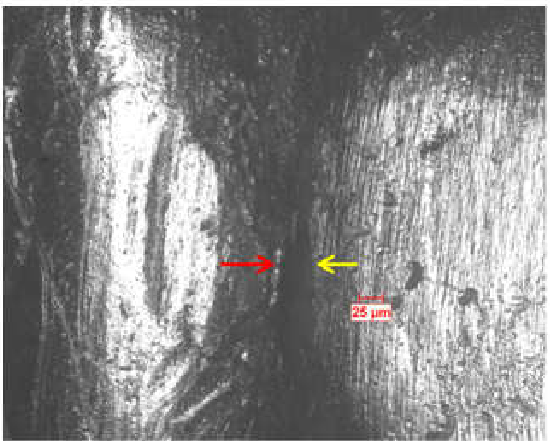

Fig 12 Marginal gap as seen under microscope

RESULTS

The descriptive statistics of mean marginal gap of different surfaces (Mesial, Distal, Buccal and Palatal) of each test group and the mean marginal gap of the groups were calculated (Table 2). The surface wise descriptive statistics of all test groups combined were also calculated (Table 3). Statistical analysis of obtained results using ANOVA (Table 4) showed that there was statistically highly significant difference between the groups *(p value ≤ 0.001)*. No statistically significant difference was observed within each groups *(p value = 0.279)* and no statistically significant interaction was observed among the groups and surfaces *(p value = 0.468)*.

Table 2 Descriptive statistics for marginal gap of different surfaces of all test groups and their mean values (in microns)

Groups	Surface	Mean	Std. Deviation	N
Group A	Buccal	48.6517	1.43895	12
	Distal	48.5300	1.19592	12
	Palatal	48.4783	1.40351	12
	Mesial	48.5433	1.17655	12
	Mean	**48.5508**	**1.26823**	**Total=48**
Group B	Buccal	49.3117	0.98063	12
	Distal	48.8967	1.45829	12
	Palatal	49.2383	1.51838	12
	Mesial	49.0650	1.02847	12
	Mean	**49.1279**	**1.23948**	**Total=48**
Group C	Buccal	61.1650	2.25361	12
	Distal	61.2267	1.17796	12
	Palatal	61.4567	1.81144	12
	Mesial	62.6767	0.91337	12
	Mean	**61.6313**	**1.69137**	**Total=48**
Group D	Buccal	65.1667	2.24922	12
	Distal	64.2283	2.56876	12
	Palatal	63.1800	3.21218	12
	Mesial	63.3233	2.62358	12
	Mean	**63.9746**	**2.72083**	**Total=48**
Group E	Buccal	67.9150	2.15380	12
	Distal	67.4950	2.09821	12
	Palatal	67.8017	2.44978	12
	Mesial	67.8683	1.77699	12
	Mean	**67.7700**	**2.07053**	**Total=48**
Group F	Buccal	70.9533	1.40003	12
	Distal	70.7100	2.09587	12
	Palatal	69.2650	2.53472	12
	Mesial	70.4267	2.82693	12
	Mean	**70.3388**	**2.29974**	**Total=48**

Table 3 Descriptive statistics for marginal gap of different combined surfaces of all test groups and the mean value (in microns)

Groups	Surface	Mean	Std. Deviation	N
All groups (Combined)	Buccal	60.5272	8.91418	72
	Distal	60.1811	8.85139	72
	Palatal	59.9033	8.57664	72
	Mesial	60.3172	8.80391	72
	Mean	**60.2322**	**8.74435**	**Total=288**

Table 4 ANOVA- Comparison of between & within the groups and surfaces

Source	Type III Sum of Squares	Df	Mean Square	F	p Value
Between	20864.784	5	4172.957	1091.960	0.001^
Within	14.762	3	4.921	1.288	0.279#
Groups * Surfaces	56.617	15	3.774	0.988	0.468#
Total	1066786.177	288			

Test conducted at 95% confidence level
In between groups- Statistically highly significant (^)
In between surfaces- Statistically not significant (#)

Scheffe's Post Hoc test comparison of mean values of each test groups (Table 5) showed significant differences among each other groups, except between Group A and Group B.

Table 5 Scheffe Post Hoc Test results of comparison between the groups

Groups	N	Subset for alpha = 0.05				
		1	2	3	4	5
Group A	48	48.5508				
Group B	48	49.1279				
Group C	48		61.6313			
Group D	48			63.9746		
Group E	48				67.7700	
Group F	48					70.3388

Test conducted at 95% confidence level

Independent samples *t* test comparison for significance among test groups (Table 6) showed statistically significant difference between Group A and Group B *(p value= 0.026)*. All other comparisons showed highly significant difference in between them *(p value ≤ 0.001)*.

Table 6 Comparison of significance amongst test groups using '*t*' test

Groups		t-test for Equality of Means			
		T	df	p Value	Mean Difference
Group A	Group B	-2.255	94	.026^^	-.57708
	Group C	-42.868	94	.001^	-13.08042
	Group D	-35.597	94	.001^	-15.42375
	Group E	-54.840	94	.001^	-19.21917
	Group F	-57.478	94	.001^	-21.78792
Group B	Group C	-41.311	94	.001^	-12.50333
	Group D	-34.403	94	.001^	-14.84667
	Group E	-53.521	94	.001^	-18.64208
	Group F	-56.250	94	.001^	-21.21083
Group C	Group D	-5.068	94	.001^	-2.34333
	Group E	-15.908	94	.001^	-6.13875
	Group F	-21.132	94	.001^	-8.70750
Group D	Group E	-7.691	94	.001^	-3.79542
	Group F	-12.377	94	.001^	-6.36417
Group E	Group F	-5.751	94	.001^	-2.56875

Test conducted at 95% confidence level
^- Statistically highly significant
^^- Statistically significant

The one way ANOVA analysis for between the group and within the group comparison of mean marginal gaps (Table 7) of combined surfaces of Group A to Group F test samples showed no significant difference among the surfaces *(p value = 0.979)*.

Table 7 One Way ANOVA: Between the group and within the group comparison of marginal gap of different combined surfaces of Group A to Group F

	Sum of Squares	df	Mean Square	F	p Value
Between groups	11.763	3	4.921	0.064	0.979#
Within groups	21930.288	284	77.219		
Total	21945.051	287			

Test conducted at 95% confidence level
#- Statistically not significant

DISCUSSION

Cast restorations restore the lost esthetics and function of a natural tooth. Over the years various materials have been used for making cast crown restorations. Robert HW *et al*[13] mentioned that for the cast restorations to be successful, the alloy should meet certain minimum requirements like strength, stability, castability, corrosion/tarnish resistance, burnishability, polishability and biocompatibility. The base metal alloy systems most commonly used in dentistry include stainless steels, nickel-chromium, cobalt-chromium, titanium, and nickel-titanium alloys. Use of Ni-Cr alloy is preferred in fabrication of fixed cast restorations due to its low cost, easy availability and ability to bind with porcelain.

Marginal accuracy of cast restorations is of high importance as faulty margins lead to periodontal issues and luting cement dissolution. Marginal gap can occur mainly due to the following reasons: 1) faulty tooth preparation, 2) faulty pattern fabrication and 3) casting shrinkage. The first two reasons are under the direct control of operator. The third one could be attributed either to operator's fault or to the alloy itself. The term marginal gap does not have a single definition. Holmes *et al*[14] provided several definitions for gap, according to the contour differences between the crown and tooth margin. Minimum gap width is the external marginal gap which is, *"the perpendicular measurement from the internal surface of the casting to the axial wall of the preparation is called the internal gap, and the same measurement at the margin is called the marginal gap"*. The absolute marginal discrepancy, which is the actual maximum gap width, is defined as *"the angular combination of the marginal gap and the extension error (over extension or under extension)"*.[14]

The importance of marginal adaptation or marginal integrity in fixed partial denture is important while considering the future dental health and the retention of fixed partial denture. Amongst all requirements of cast crown restorations, marginal accuracy is most important because poor marginal fit allows passage of fluids and bacteria into the gap and may predispose many health related issues. Sensitivity of a vital tooth prepared for receiving a cast crown restoration is usually the first symptom with which a patient meets a dental professional. This sensitivity could be majorly due to a vertical marginal discrepancy of the restoration. The marginal gap, either vertical or horizontal can result in accumulation of food debris and plaque. This results in halitosis which can psychologically disturb the patient. A poorly adapted cast crown restoration causes too much mechanical irritation to surrounding tissues and enhances plaque accumulation with subsequent periodontal problems. This starts initially as gingival inflammation with bleeding to gingival recession and further periodontal break down. It is believed that the extent of misfit of dental restorations is closely associated with the development of secondary caries and periodontitis.[15-17] With passage of oral fluids through the marginal gap, dissolution of the luting cement takes place initially in a slow pace and then rapidly.[18] This will ultimately lead to compromised retention of cemented restoration.

Recasting of alloys could be promoted while considering the fact that these alloys are depleting day by day and their cost is increasing due to the higher demand. Palaskar J *et al* [3] studied recasting of Ni-Cr dental alloy by adding varying percentage of once cast alloy with new alloy and concluded that the castability value of all the groups had no significant difference. Presswood RG[19] stated that, there was no considerable reduction of the elements after recasting. The colour evaluation and the chemical analysis established that no notable change in the composition of Ni-Cr alloy occurred even after six melts of the original alloy. Study by Nelson *et al*[20] showed that each subsequent generation of recastings demonstrated a degenerative trend in physical properties. But if strict adherence to clean technique is followed, these degenerative changes in physical properties and micro structure could be minimized.

Repeated melting of the alloy can result in volatilization resulting in potential loss of certain trace elements like beryllium, iron, silicone and manganese. This volatilization or oxidation of trace elements ultimately results in excessive solidification contraction. The loss of trace aluminum present in the dental alloy during recasting may lead to increase in melting temperature of the resultant metal and this may also affect the ability of the molten metal to fill the mold in quality similar to that of fresh metal. Composition of the alloy used for casting is also very important while considering the marginal gap formation. The presence of beryllium (Be) in Ni-Cr alloys creates a Ni-Be eutectic phase, with a lower melting point than the remaining phases.[21] This results in obtaining a more fluid metal alloy, with a lower melting point, reducing the casting shrinkage. It's assumed that, with Be, a lower cervical discrepancy would be obtained.[21] But the toxic effects of Be undermines its superiority in casting properties. It is also necessary to consider that no significant difference was observed in terms of flow properties obtained with Be free Ni-Cr alloy.[21]

A study by Schwartz IS[22] described different methods and techniques to improve fit of the cast restorations in which he advices to over wax the margins of the wax pattern to get a better marginal fit. Values ranging from 50μ to 200μ for marginal gap have been considered as clinically acceptable by different authors.[22-25] In the present study, once cast Beryllium free Ni-Cr dental casting alloy was added to fresh alloy in varying percentage by weight and the marginal accuracy was measured as the distance between the master die finish line to the margin of the cast crown. As all the procedures like materials used, pattern fabrication, spruing, investing, finishing and measuring marginal gap were carried out in a similar manner for all test groups by a single operator, the only variant was the amount of once cast alloy used. Second generation recasting of alloy showed highest value of marginal gap in the present study. This could be due to the increased loss of trace metals from the alloy occurring from volatilization during repeated melting, resulting in reduced flow properties and increased casting shrinkage.

Results from the study showed that least marginal gap was observed when only fresh alloy was used (Group A). With increase in the amount of once cast alloy by weight percentage, the marginal gap also increased considerably, compared with control group cast completely with new alloy. These results were in accordance with few earlier studies.[11,12,23]

CONCLUSION

Even though the test results showed statistically significant increase in the marginal gap with increase in amount of recasted alloy, all these marginal gap measurements observed were less than 100μ which is within clinically acceptable limits. From the present study, the addition of once cast alloy with fresh alloy for casting procedures could be considered practically acceptable with respect to marginal accuracy, resulting in greater savings both economically and environmentally. Further studies using the same materials and techniques are essential to confirm the level of elemental release, changes in mechanical and physical properties of the casting alloy used in the present study.

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