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ORIGINAL RESEARCH

Effect of marginal integrity of nickel- chromium crowns using different casting techniques made with different percentages of reusable alloys – An invitro study

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Abstract
Introduction: Base metals have an extensive use in casting methods. Sometimes they are reused in laboratories which may have an adverse effect on the restoration marginal integrity. This study aimed to investigate the effect of recasting of alloys on marginal integrity of restorations using different casting techniques.
Materials and methods: master die (Fig.1) was designed and prepared in lath to simulate full coverage PFM crown preparation with chamfer margin around entire circumference. Preparations were standardized with height of 8mm, convergence angle of 6 degree, 1mm chamfer width and anti rotational surface. Using this master die 96 wax patterns were fabricated. This wax patterns were divided into two groups with 48 patterns in each group based on the casting techniques i.e., conventional casting technique and accelerated casting techniques. Each group of patterns were cast with four different percentage compositions of reuse Ni-Cr alloy, (Bego,Germany)i.e,100% new alloy, 25% weight of recast alloy, 50% weight of recast alloy, 100% recast alloy respectively.
Results: Mean vertical marginal discrepancies of Conventional and Accelerated castings were compared, statistically significant differences were found between the mean vertical marginal discrepancies of Conventional and Accelerated castings. Using different percentage weights of reusable Ni-Cr alloy ($P<0.001$).
Conclusion: marginal accuracy of cast copings fabricated by accelerated casting technique and conventional casting technique using 100% new alloy was greater than 25%, 50%, and 100% recast alloy.
Clinical significance: Clinically acceptable complete castings can be obtained with accelerated casting technique using recast alloy in varying percentage with new alloy.
Key words: marginal fit, accelerated casting, reusable alloy.

Introduction
The minimization of crown and fixed partial denture marginal gaps is an important goal in prosthodontics.[1,2] Precise marginal adaptation is necessary to achieve better mechanical, biological and esthetic prognosis of the restorations. Inaccurate marginal fit is responsible for plaque retention, micro leakage and cement breakdown and permits penetration of bacterial components along with the saliva through these gap. Poor internal fit of a coping can increase

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the thickness of the cement and thus influence the mechanical stability of dental restorations.[3] Earlier cast gold alloys were considered to be the standard material of choice for the fabrication of crowns in dentistry. However, these cast gold alloys were replaced by base metal alloys because of their high price. The subsequent demand for semiprecious and non precious base alloys in dental procedures has now resulted in substantial increases in the price of these once insignificant alloys, again to a point of financial concern.[4,5] Base metal alloys have wider use in casting methods. However, these base metal alloys were then so economical that every time casting was done using new metal pellets and remaining leftover metal was either discarded or sold back to the supplier. But shortly due to increasing popularity for the base metal alloys, their cost has risen to a large extent.[6] Many materials and numerous methods have been suggested for fabrication of dowel and cores, complete crowns, and fixed partial dentures (FPDs). The conventional investing and casting procedures for these restorations call for a minimum 1-hour bench set for investment, followed by a 1- or 2-stage burnout procedure before casting. The whole process requires 2 to 4 hours for completion. According to the accelerated casting technique, the dowel and core and the complete crowns can be invested and cast in 30 minutes.[7,8,9]

Materials &methods

A master die (Fig.1) was designed and prepared in lath to simulate full coverage PFM crown preparation with chamfer margin around the entire circumference.

Fig1: Brass die

Preparations were standardized with height of 8mm, convergence angle of 6 degree, 1mm chamfer width and anti rotational surface. This brass dies mounted on a cylindrical base of 8mm diameter and 20mm length. On this brass die, impression is made with polyvinyl siloxane material and poured with type 4 dental stone. For wax pattern fabrication, dip wax technique is used. For this technique, Inlay wax (YETI PRODUCTS, GERMANY) is used and shaped by waxing instruments to follow the emergence profile of die. Thickness of wax pattern was 0.5mm which is measured with wax gauge. After the pattern had cooled, the margins were readapted and refined using wax carving instruments. This wax patterns were divided into two groups with 48 patterns in each group based on the casting techniques i.e., conventional casting technique and accelerated casting techniques.

Group 1: representing castings made following conventional casting technique using
Group 1A: 100% new alloy
Group 1B: 25% wt. of recast alloy
Group 1C: 50% wt. of recast alloy
Group 1D: 100% wt. of recast alloy
Group 2: representing castings made following accelerated casting technique using
Group 2A: 100% new alloy

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Group 2B: 25% wt. of recast alloy
Group 2C: 50% wt. of recast alloy
Group 2D: 100% wt. of recast alloy

Then wax patterns were invested in phosphate bonded investment material (BREVEST DELTA PRODUCTS, Germany) at 40ml /160g (W/P ratio) according to manufacturer instructions. For conventional casting technique, A two stage wax elimination cycle was used in this study in accordance with the manufacturer's recommendations. The temperature of the furnace was raised at the rate of8°C/min up to 427°C for the first cycle and then at the rate of 14°C/min up to 815°C for the second cycle. The usual burnout temperature for phosphate after burnout using centrifugal casting machine. Group 1 patterns were casted using reusable Ni-Cr alloy in different percentage weights. Whereas group 2 patterns were casted using accelerated casting technique (Fig:2).

Fig2: Metal copings (conventional + accelerating)

For the accelerated casting technique, after the bench set time of 20 minutes, the set investment was placed in the burnout furnace (SirioDental SNC, Italy). The molds were placed, in an oven which was preheated to 815 degree Celsius for 20 minutes. Completed castings were seated on the metal die under finger pressure. The marginal discrepancy between the metal die and the castings were measured at 100x magnification on an optical stereo microscope (Fig.3) at mesial, distal, buccal and lingual positions using image-pro plus version-6.2 software.

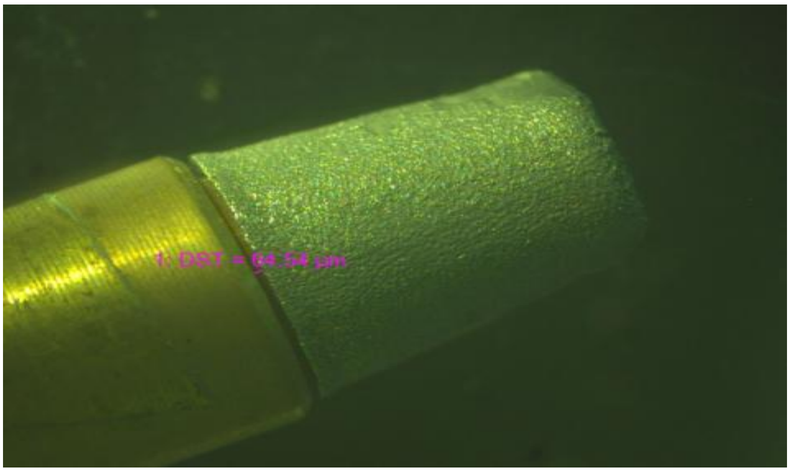

Fig3: Brass die with metal coping

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Results

Statistical analysis for present study was done using SPSS (IBM SPSS-(statistical package for the social sciences) STATISTICS FOR WINDOWS, VERSION 22.0 AND ARMONK NY:IBM Corp. released 2013) .To analyze the data parametric methods were applied. Comparison of conventional casting technique using 100% new alloy, 25%, 50% and 100% wt of recast alloy

	Group 1A		Group 1B		Group 1C		Group 1D		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Buccal	54.25	14.46	113.37	36.00	119.09	29.09	166.85	35.788	<0.001**
Palatal	55.88	16.76	117.21	28.63	124.06	29.56	170.54	36.99	<0.001**
Mesial	53.86	7.84	115.04	30.67	116.56	25.33	173.16	23.85	<0.001**
Distal	55.40	16.69	126.71	24.54	113.60	12.98	167.02	48.97	<0.001**

ANOVA test used. ** highly significant

The mean marginal gaps were more for group 1D(conventional casting technique using 100% recast alloy) when compared to groups 1A,1B,1C. The difference was statistically significant(p-≤0.005)

Comparison of accelerated casting technique using 100% new alloy, 25%, 50% and 100% wt of recast alloy

	Group 2A		Group 2B		Group 2C		Group 2D		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Buccal	46.96	11.35	106.86	24.07	128.64	33.91	148.94	28.90	<0.001**
Palatal	48.88	10.15	120.79	32.89	126.95	40.78	140.02	28.92	<0.001**
Mesial	47.91	13.85	111.09	24.41	128.04	32.22	124.40	25.02	<0.001**
Distal	46.05	10.28	118.81	32.05	110.68	18.54	138.83	29.08	<0.001**

ANOVA test used. ** highly significant

The mean marginal gaps were more for group 2D (accelerated casting technique using 100% recast alloy) when compared to groups 2A, 2B, 2C. The difference was statistically significant (p-≤0.005)

Discussion

This study compared the marginal gap of metal copings fabricated by conventional and accelerated casting techniques using reusable Ni-Cr alloy in different percentage weights.[10,11,12] The results supports a rejection of the null hypothesis, as there were differences in the marginal gaps among eight differently fabricated coping groups. However the marginal discrepancy of all groups was within the clinically acceptable range, of around 100 µm.[13,14,15] Survival of fixed prosthetic constructions is conditioned by a number of factors the most special and significant of which is marginal and internal fit of restoration. Restoration adaptation might be affected by a number of factors such as design preparation, localization of finish line, restoration material and mold technique, fabrication method, the type of cement, dentist's skills, the type of finish line etc.[16] The marginal "fit" of any dental restoration is vital to its long-term success. Lack of adequate fit is potentially detrimental to both the tooth and the supporting periodontal tissues.[17] unlike physical and mechanical properties of materials; the fit of a restoration has never been strictly defined. The reference points for measurements and the descriptive terminology defining fit vary considerably among investigators. Often the same term is used to refer to different measurements, or different terms are used to refer to the same measurement. This is a constant source of confusion in reporting and comparing studies.[18] In general, marginal gap and internal gap of restorations are very much influenced by clinical and laboratory factors. Clinical factors include geometry of tooth preparation, and degree of taper, type of finish line, impression

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materials, and cement used to lute the restoration in dental office.[19] Laboratory factors that affect marginal gap and internal gap are compatibility of dental materials such as wax, casting techniques, die stone and, die spacer, and the casting investments.[20] The present study is to evaluate the influence of casting techniques and reusable alloy in different percentage weights on marginal gap of cast copings. The fit of a casting can be defined best in terms of the “misfit” measured at various points between the casting surface and the tooth. Measurements between the castings and the tooth can be made from points along the internal surface, at the margin, or on the external surface of the casting.[21] 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 vertical marginal misfit measured parallel to the path of draw of the casting is called the vertical marginal discrepancy. The horizontal marginal misfit measured perpendicular to the path of draw of the casting is called the horizontal marginal discrepancy.[22] There is also the possibility of overextended or under extended casting margins. An overextended margin is the perpendicular distance from the marginal gap to the casting margin. An under extended margin is the perpendicular distance from the marginal gap to the cavosurface angle of the tooth. The angular combination of the marginal gap and the extension error (overextension or under extension) is called the absolute marginal discrepancy.[23]The absolute marginal discrepancy is measured from the margin of the casting to the cavosurface angle of the preparation. When no overextension or under extension is present, the absolute marginal discrepancy is the same as the marginal gap.[24]When no marginal gap is present, the absolute marginal discrepancy is the same as the overextension or under extension. Lack of seating of a casting as measured perpendicular to the path of draw by an arbitrary point (or points) on the external surface of the casting and tooth away from the margin is called the seating discrepancy.[25]Numerous data have been published regarding the clinically acceptable marginal gap of crown in the current literature. The study of Christensen et al.[26] identified the range of 34-119 μm as an acceptable value for sub-gingival marginal gap, and also 2-15μm for supra-gingival marginal gap. However, Maclean and Von Franunhofer [27] studied more than 1000 restorations in a 5- year study and reported 120μm as the maximum value for a clinically- acceptable marginal gap. Based on these studies the amount of marginal discrepancies measured in this present study could be rated as good for conventional casting technique and acceptable for accelerated casting technique. In clinical practice human teeth shows very much variation because of their individual structure and age causing difficulties in getting standardized abutments. Because of this, standardized brass dies were used in this study for measuring marginal gap. To normalize the measurement all the procedure for 8 subgroups were standardized except casting techniques and different percentages of reusable alloy. For instance standardized brass dies had the same 6 degree taper, same method for wax pattern fabrication, equal cement space with uniform thickness of 30 microns and same investing material but different casting techniques and different percentages of reusable alloy were accomplished and a finger pressure used for placement of copings on the brass die. Therefore, it was possible to compare the marginal gap of the copings focused on only casting techniques and amount of reusable alloy used. Fabrication of accurate pattern is a key factor that can affect the marginal adaptation and internal fit of castings. Traditionally, patterns for these restorations have been constructed from inlay casting wax. This technique combines familiarity and ease of manipulation with good reproduction of details and low cost. In the same time, waxes have two main disadvantages; a high coefficient of thermal expansion and tendency for stress relaxation.[28]This is an important issue which must be deliberated in any technique that accompanies delayed investment or includes heating the wax pattern prior to investing procedure or complete setting of the investment. A low-storage temperature is therefore recommended to minimize distortion and moreover, to obtain an

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ideal result, the patterns should be invested instantly after being removed from the preparation. In this study all the wax patterns were fabricated manually using dip wax technique. Advantages are economical, minimal technical experience. But the disadvantages using conventional wax pattern are time consuming, the wax-ups quality is dependent on the skill of the individual.[29] The study of Sushma et al. with promise to the notions of pattern fabrication, showed that the inlay pattern wax – if invested instantly- it can be considered as an acceptable material for fabrication of a casting with minimal marginal discrepancy; reminding that this pattern material is cost-effective and less technique-dependent. Phosphate bond investment material exhibits high strength makes it possible to resign the use of casting ring used for investing procedure. The ring less technique is easier, less expensive and gives clinically acceptable castings.[30] Because of its advantage, in our study phosphate bonded investment material is used. The "conventional casting" technique has been used since long time, and it has become common practice in dentistry after it was documented by Taggart in 1907. The conventional casting is time consuming and requires approximately 2 to 4 hours for completion. There have been numerous reports mentioned to perfect the casting procedure in dentistry after improvisation in dental material science. Accelerated casting technique has been reported in an effort to achieve similar quality results in comparison to conventional casting technique significantly in less time that is approximately in 30 to 40 minutes. Although researchers have documented that, accelerated casting technique can be successfully employed for the fabrication of post and core and single full crown restorations, but on reviewing and critically analyzing the literature it is found that there is further scope for the studies, to know about the success of the accelerated casting technique to achieve quality cast restoration and fixed partial dentures. [31] In our present study both conventional and accelerated casting techniques were used to compare the accuracy of marginal gap of cast copings. Fixed Prosthodontics has become a major part of current restorative dentistry because people are living longer, seeking more dental care, and are more knowledgeable about their dental health. In view of their convenience and psychological and social advantages, patients prefer reconstruction with fixed partial dentures (FPDs) rather than removable partial dentures. [32] Robert HW et al mentioned that for the cast restorations to be successful, the alloy should meet certain minimum requirements like stability, strength, burnish ability, cast ability, corrosion/tarnish resistance, polish ability and biocompatibility. The ideal restorative material was gold alloy because of its excellent properties, such as tarnish and corrosion resistance, capacity to take high polish, cast ability, and burnish ability, hardness, strength, and percentage elongation. However, due to high cost and unaesthetic appearance, this alloy is not used now, which led to increase in demand for semiprecious and non precious base metal alloys. Most of the properties of the base metal alloys meet the requirements of gold alloy with added advantage of low cost and reduced specific gravity.[33] The base metal alloy systems most commonly used in restorative dentistry include stainless steels, nickel-chromium, and cobalt-chromium, titanium, and nickel-titanium alloys. In our present study Use of Ni-Cr alloy is preferred in fabrication of cast copings because of its low cost, easy availability. The original non precious metal alloys introduced into dentistry 15 to 20 years ago were so inexpensive that the new ingots were melted, cast, and discarded or sold back to the supplier by the pound as scrap, even though they were purchased by the pennyweight or ounce. When using the inexpensive non precious alloys, technicians used all new metal for each casting instead of mixing new metal with previously melted ingots. [34]The current demand for the base metal alloys has resulted in a substantial increase in there price. Other than the cost due to environmental factors and deprivation of the resources every material is being tried to recycle for various purposes. Therefore efforts are being made to recycle or to recast the alloy again and again with or without adding a new alloy. Repeated casting has shown more stability in noble and nickel-based alloys in comparison with the

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high noble alloys. Recasting of nickel-chromium alloys has revealed no meaningful effect on their castability.[35] A study conducted by hesby et al on Physical properties of a repeatedly used non precious metal alloy, concluded that, the tensile strength, percentage of elongation, and hardness properties were determined and compared. There were no significant differences observed in the physical properties tested among any of the four generations of casting. This finding indicates that the metal can be reused for at least four generations. Various authors have studied the effect of recast base metal alloys on crowns marginal accuracy and found maximum marginal fitness in 100% new alloy castings and minimum fitness in 100% reused alloy castings. While the marginal fit with 50% new and 50% reused alloy was less than 100% new alloy but was clinically acceptable. Similar studies were carried out by lopez et al; they stated that marginal fitness of new alloy was more ideal when compared to that of recast alloy. Lopez declared that oxidation, vaporization, porosity are all responsible for the difference between recasted and new alloy marginal gap. All the studies carried out earlier concluded that even though the marginal accuracy of the castings made with using recast alloy in different percentages is less when compared to new alloy, they can still be used with 50% reused alloy as the marginal loss is within the maximum tolerance limit. Results from this study showed that least marginal gap was observed when 100% new alloy was used. With increase in the amount of reusable alloy by weight percentage, the marginal gap also considerably increased when compared with control group cast completely with new alloy. These results were in accordance with few earlier studies.[36] Konstantoulakis et al. (1998) [37,38] and Schilling et al. (1999) [39,40] reported that crowns fabricated with the accelerated casting technique were not significantly different from those fabricated with conventional technique. Accelerated castings show more marginal discrepancy than the conventional castings, but previous studies have stated that these marginal discrepancy values are well within the clinically acceptable limits. Mean vertical marginal discrepancies of Conventional and Accelerated castings were compared, and statistically significant differences were found between the mean vertical marginal discrepancies of Conventional and Accelerated castings using different percentage weights of reusable Ni-Cr alloy ($P<0.001$) Clinical tolerance limits for the fit and marginal adaptation of a cast restoration are actually not known.

Conclusion

Within the limitations of this study and the material and methods used, the following conclusions may be drawn;

1. Accelerated castings show more marginal discrepancy than the conventional castings, but there is statistically no significant difference between the two casting techniques.
2. The marginal accuracy of cast copings fabricated by accelerated casting technique and conventional casting technique using 100% new alloy was greater than 25%, 50%, and 100% recast alloy.
3. Clinically acceptable complete castings can be obtained with the accelerated casting technique using recast alloy in varying percentage with new alloy.

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