

Marginal integrity of metal copings of various porcelain fused to metal alloys using different ring casting techniques: A systematic literature review

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ABSTRACT

Precise marginal seating of fixed prosthesis over prepared abutments is crucial to fulfill biological, physical, and cosmetic requirements. Accurate fit of the restoration margins to the prepared finish line is necessary to prevent gingival inflammation, secondary caries acting as an important indicator of the overall acceptability of the cast restoration. The clinical success with porcelain fused to metal restorations lies in achieving both predictable esthetics and function. The design of the tooth preparation can have an effect upon laboratory and clinical success of individual restorations and types of restorations. The accuracy of casting holds the key to long-term success with these restoration. The presented literature review is an attempt to highlight the historical approaches, various pioneer researches, different controversies, difficulties, and current trends for casting of metal employing various techniques. A detailed literature search was conducted using MEDLINE/PubMed databases and other scholarly research bibliographic databases using Medical Subject Headings (MeSH). Studies describing research studies and *in vitro* studies were retrieved and evaluated from 1955-2013.

KEYWORDS: Chromium alloys, dental casting technique, marginal fit

Introduction

Metal fused to ceramic restorations have been a gold standard for fixed replacement of missing teeth since many years. Various studies have reported that porcelain fused to metal restorations can be successfully used for fabrication of fixed partial dentures.^[1] The increased popularity of porcelain fused to metal restorations is due to ever increasing esthetic demands, improvement in casting techniques and alloys along with wide application in all clinical situations including even complex restorative needs.^[2] Tooth preparation for fixed prosthesis should respect the biomechanical guidelines involving the biological, mechanical, and esthetic factors for optimum success.

Precise marginal fit is an essential and critical factor for a

successful dental cast restoration as intraoral degradation of cement can result in loss of marginal seal and promote retention of plaque. Marginal fit of the casting is one factor that can lead directly or indirectly to development of secondary dental caries, adverse pulpal reaction, and periodontal disease.^[3,4] Marginal seal essentially depends on the surface characteristics of the margins, adaptation of casting, and the luting cement used. Improper marginal seal can encourage plaque and bacterial deposition resulting in secondary caries and periodontal disturbances with concomitant deterioration of the restoration. Inadequate fit of a coping due to poor marginal seal can lead to a thin line of the cementing medium exposed to the action of saliva, foreign bodies, and oral fluids, encouraging problems under the restoration and finally tooth loss.^[5] Increase in the cost of gold in 1970's shifted the focus on development of alternative alloy systems.^[6,7] The search for low cost alloys led to the introduction of noble and predominantly base metal alloys for fixed prosthodontics. Noble alloys have lower percentage of gold with silver, palladium, and platinum. Base metal alloys constituted of predominantly nickel, chromium, and cobalt.

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Today, numerous low gold and base metal alloy systems are being developed and marketed for dental applications. These alloy systems are now used extensively to make cast restorations, particularly for metal substructures of ceramometal crowns. In selecting an alternative alloy for a cast restoration, one of the several important factors to be considered is the dimensional accuracy of resultant casting. The casting must adapt precisely to the prepared tooth, with a good marginal fit.^[8] It is gratifying to elicit in nongold alloys that some desirable properties are better than those of gold alloys. Their increased hardness and strength are of great significance as they play an important role in conservation of tooth structure by requiring lesser amount of tooth reduction for restoration with these alloys. However, these alloys are difficult to burnish at the margins. Their marginal approximation can, thus, be a compromising factor and achievement of hermetic seal can be questionable with their use. The need of a casting ring for phosphate bonded investment was not questioned till now as it was a standard and an established procedure. According to recent studies, the high strength of these investment materials makes it possible to abandon the use of the casting rings. The ringless techniques are easier, less expensive, and give clinically acceptable castings. The advantage of a ringless technique is not the restriction of thermal expansion that is associated with the presence of the metal ring. In the literature, there are very few studies to support the assumption that ringless casting technique can produce accurate castings for fixed partial dentures. This review is an attempt to present an overview on the different methods and theories for different casting technique employed for precise marginal fit, where the authors look forward for some new-fangled *in vitro* studies on wider parameters to substantiate and determine certain materialistic guidelines in this perspective.

Methods of literature search

Scholarly search bibliographic databases (PubMed, PubMed Central, Medline Plus, Cochrane, Medknow, Ebsco, Science Direct, Hinari, WebMD, IndMed, Embase) and textbooks were explored until May 2013 using MeSH (Medical Subject Headings; PubMed) based keywords such as “Dental Casting Technique,” “Chromium Alloys,” “Marginal Fit.” The search was limited to reviews, systematic researches, and meta-analyses in various dental journals published over the last 65 years in English and Spanish. A total of 78 articles were identified; however, after examining the titles and abstracts, this number was finally condensed to 43 articles.

Systematic review of literature

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 supporting periodontal tissues. Accuracy of the fit of casting is essential for longevity and clinical success of the cast restorations in the oral cavity. The accuracy of casting depends on method and material used for its construction. Though many studies have been

undertaken to study the marginal fit but the marginal accuracy of these material by routinely used casting techniques has not been substantially established in the literature. For the ease of understanding, this review has been covered under following headings:

- Metal ceramic alloys
- Margins and marginal fit
- Casting and investment techniques.

I - Reviews related to metal ceramic alloys

Brecker^[9] discussed the construction of porcelain baked to an iridio platinum alloy, porcelain baked to palladium alloy, and porcelain baked to gold alloy. He mentioned that close marginal adaptation of metal ceramic crown to the gingival finish lines of a prepared tooth protects the pulp from bacterial invasion, thermal conduction, and thermal irritation. Later on, Silver *et al.*,^[10] evaluated and compared the change in the fit with the porcelain fused to cast metals, porcelain fused to platinum palladium group of alloys, and porcelain fused to gold alloys and put forth their views that, if the metal is ground to an optimal thickness of about 0.5 mm at its thinnest portions in preparations to receive the porcelain, their thinning beyond this, particularly at the margins of the casting, the shrinkage of the porcelain may buckle or contract metal at these thin areas, causing a change in fit. They also concluded that the higher fusing porcelains and metals are stronger, more stable, and present the greatest technical latitude. Wight *et al.*,^[11] conducted a study for the evaluation of three variables affecting the casting of base metal alloys namely the effect of venting, sprue width, and thickness of investment covering the end of the pattern. In their study, they used methyl methacrylate resin for the fabrication of casting patterns and regarded them better in strength, ease of manipulation and measurement, and lack of distortion. They also found that all the vented samples with sprue widths of 2 mm or more were defect-free, whereas the corresponding unvented samples had extensive voids and porosity not in all but one casting. All castings with a sprue width of 1 mm were defective regardless of whether or not vents were used. The thickness of the investment above the pattern had no effect on casting results.

Duncan^[12] studied the casting accuracy of nickel-chromium alloys for fixed prosthodontic work. He found out that on comparing with gold alloys, nickel-chromium alloys have a wide range of physical and mechanical properties like higher yield strengths and moduli of elasticity, greater percentage of elongation, which is an index used to predict burnishability. Because of their high yield strength, susceptibility to strain hardening and high modulus of elasticity, greater force is required to deform and burnish nickel-chromium alloys. Thus, they concluded that nickel-chromium alloys did not cast as consistently or as accurately as precious alloys and a further study was needed to determine their singular effects.

Vermilgea *et al.*,^[13] investigated the casting accuracy of five base metal alloys (Biobond, Ceramalloy II, Unibond, Biocast, and Neobond) and three investment material (Ceramigold 2 and Hi-Temp and Neoloy Hi-Heat Crown and Bridge Investment). The result of this study showed that only 8% was adequate casting, while 23% oversized 49% undersized. They found that there is effect of investment material on the casting accuracy because overall, the fit of the test castings was poor and individual alloy-investment interaction was significant. Although they marketed for use with base metal alloys, it was seen that investment manufacturer's recommended techniques require alteration to enhance the fit of base metal restorations. Later on, Shiratsuchi *et al.*,^[14] conducted an *in vitro* study to evaluate the influence of finish line design on marginal adaptation of electroformed metal-ceramic crowns. They prepared three steel dies for maxillary central incisor crowns with three finish line designs: Shoulder, rounded shoulder, and deep chamfer preparations. Eight standardized electroformed metal-ceramic crowns were fabricated for each group. Marginal discrepancies were measured at 60 points for each specimen along circumferential margins at four sites. They found that the lowest range of median marginal discrepancy was found for deep chamfer preparations and highest values for shoulder preparations. Recently, Paulino *et al.*,^[15] compared the castability of pure titanium with Ni-Cr and Ni-Cr-Be alloys. The degree of marginal rounding was measured and margin length deficiencies (μm) were calculated. Sixty acrylic resin crown patterns with wax margins were prepared on a stainless steel crown die having a 30° beveled finish line. The degree of wax margin rounding was determined in the control group (group W, $n = 15$). The remaining 45 crown patterns were divided into three groups ($n = 15$) and cast in commercially pure titanium (Tritan, group Ti), Ni-Cr-Be alloy (Verabond; group VBI), and Ni-Cr alloy (Verabond II; group VBII). Margin configurations for both wax patterns and cast specimens were measured and recorded with the same method, using silicone impressions of the margins. After polymerization, the silicone material was sectioned in eight locations through the margin area so that cross sections of the margins could be observed. It was seen that the castability of titanium was poor compared to Ni-Cr-Be alloy, but similar to Ni-Cr alloy.

II - Review related to margins and marginal fit

Hung *et al.*,^[16] evaluated the marginal fit of porcelain fused to metal and two types of ceramic crowns Dicor and Cerestore. Ten premolars free of caries were prepared for each type of restoration and crowns were made. The vertical marginal openings were measured before cementation, after cementation, and after thermocycling. All 30 cemented crowns were then embedded in acrylic resin for serial section for measurement of absolute marginal openings. They concluded that marginal openings increased after cementation and after thermocycling and porcelain fused to metal crowns had significantly better marginal fit than that of ceramic

crowns. Later on, Felton *et al.*,^[17] discussed the effect of air abrasives on marginal configurations of porcelain fused to metal alloys. Separate dies were milled to produce chamfers, beveled shoulder, and shoulder margin configurations. The angles at margins were 20°, 45°, and 90° to represent beveled shoulder, chamfer, and shoulder designs, respectively. Each die was used as a master model for production of castings using five different type of base metal alloys (Jelanco O, Cameo, Olympia, Jelstar and Genesis II). The abrasives were aluminium oxide (15-45 μ) and glass beads (40-80 μ). This investigation evaluated the extent and significance of this procedure and found that marginal abrasion ranged from 5 to 110 microns. They concluded that air abrasion with aluminum oxide or glass beads shortened all the three types cast margins on all of the alloys. The smaller the margin angle, greater was the loss of alloy after air abrasion. Tjan *et al.*,^[8] conducted an *in vitro* study to evaluate the marginal accuracy of complete crowns made from alternative casting alloys (low-gold-palladium, high palladium, silver-palladium, nickel-chromium-molybdenum). They measured the marginal accuracy of complete cast crowns made from five alternative casting alloys and compared with that of crowns made from the traditional type III gold alloys, which served as a standard for comparison. Alternative alloys studied were low-gold-palladium, high palladium, silver-palladium, nickel-chromium-molybdenum, and copper-aluminum. They found out that silver-palladium alloys crowns exhibited the best marginal accuracy among the alternative alloys tested. However, the values of marginal discrepancy were still slightly higher than that of crowns made of type III gold-alloys. Conversely, nickel-chromium-molybdenum alloys crowns exhibited the poorest marginal accuracy. In another similar study, Vahidi *et al.*,^[18] evaluated the marginal adaptation of all-ceramic crowns and metal ceramic crown systems. They selected 22 recently extracted premolars for the study. Twelve teeth were selected for the Renaissance crowns (William Gold Refining Co. Inc., Buffalo, N.Y.) and five for Dicor crowns (The marginal adaptation of Renaissance crowns was compared with that of widely used metal ceramic and Dicor crowns (Dentsply International Inc.) and five were beveled to receive metal-ceramic crowns. The finished crowns were studied by observation of the impression made with elastic material (calotene). The crowns were permanently cemented to the preparation with the polycarboxylate cement. The cemented crowns were embedded in the resin and sectioned and observed under light microscope under 100 × The Renaissance crowns demonstrated a mean cement thickness of 76 μm . The marginal opening of the metal ceramic crowns (mean 37 μm) was approximately half that of Renaissance crowns. Dicor crowns showed the lowest marginal opening, with an average of 30 μm .

Kern *et al.*,^[19] clinically evaluated the influence of two trituration capsule cement systems on the marginal fit of inner copings for telescopic crowns. Using a randomized

parallel design study, one coping was cemented using zinc phosphate cement (Phosphacap) and one using glass ionomer cement (Ketac-Cem Maxicap) for each patients. The result of this study was that the mean marginal discrepancies for all cast copings were approximately 30 (μm) before cementation, and increased significantly after cementations to 86 (μm) in the zinc phosphate copings but to only 47 (μm) in glass ionomer cement copings. Later on, Valderrama *et al.*,^[20] compared marginal and internal adaptation of titanium and gold-platinum-palladium metal ceramic crowns. The marginal and internal adaptation of metal ceramic crowns fabricated by electrical discharge machining and conventional metal ceramic alloys were compared. The crowns were cemented using zinc phosphate cement, embedded in epoxy resin, and sectioned in to two planes, that is, diagonal and buccolingual. The crowns were then measured at nine sites. The result showed that there were no statistical differences between the external marginal opening of the titanium and gold-platinum-palladium metal ceramic crowns.

Gemalmaz and Alkumru^[21] studied the marginal fit changes that occur during the porcelain firing cycles of palladium-copper and nickel-chromium copings both with shoulder and chamfer finish lines were investigated with scanning electron microscopy. Three copings from each alloy test group were used as unveneered controls. Comparisons of the firing cycles revealed a greater change during the degassing stage, and the opaque firing caused a decrease in marginal gap. There was a small increase in gap size after firing body porcelain. The marginal fit change for the palladium-copper copings (19.39 microns) during degassing was significantly greater than that for the nickel-chromium copings (8.65 microns). However, no significant differences were found when the effects of margin design and porcelain proximity to fit of metal-ceramic crowns were compared.

Piemjaj^[22] conducted an *in vitro* study to determine the effect of seating force, margin design, and cement on marginal seal and retention of complete metal crowns. They prepared crowns with three finish lines-Chamfer, shoulder, and shoulder with a 45° on a premolar-shaped master die. Three different seating forces – 25, 100, and 300 N were used to load the crowns until initial set of the cement. They concluded that the higher seating forces produced better crown seating but had no significant effect on crown retention. In the same year, Yeo *et al.*,^[23] conducted a study to compare the marginal adaptation of single anterior restoration made using three different systems of porcelain crowns. The *in vitro* marginal discrepancies of 3 different all ceramic crown systems (Celay In-Ceram, conventional In-Ceram and IPS Empress 2) and a control group of metal ceramic restoration was evaluated and compared by measuring the gap dimensions between the crowns and the prepared teeth at the marginal openings. They concluded that the marginal discrepancies were all within the clinically acceptable values set at 120 μm . However,

the crowns made from IPS Empress 2 system showed the smallest and most homogenous gap dimensions, whereas the conventional In-Ceram system produced the largest and more variable gap dimensions as compared with to that of metal ceramic (control) restorations.

Jahangiri *et al.*,^[24] assessed the effect of preparation design on marginal adaptation. In addition, they also evaluated the sensitivity and specificity of clinical evaluations of marginal adaptations of cast restorations which was compared by stereomicroscopy. Three Ivorine molar teeth of differing designs were prepared: Group I consisted of a complete crown preparation with a chamfer finish line, Group II consisted of complete crown preparation with a buccal shoulder and beveled finish line, and Group III consisted of a three-quarter crown preparation with proximal boxes and beveled finish line. Twenty-four castings ($n = 8$) were waxed and cast using alloy with a composition of 12% silver, 67% copper, and 20% zinc (Ney technique casting metal; Degussa-Ney Dental Inc), 12 circumferential sites were identified for examination on each casting using a stereomicroscope, which were interpreted using a software (Bioquant 98). The clinical examinations included explorer examination to detect marginal gap by tactile feel, followed by examination with a disclosing media (GC Fit Checker, United States). The result of the study was that the marginal adaptation of different preparation designs was not significantly different. Clinical detection, with similar sensitivity and specificity as the stereomicroscope, occurred at marginal openings greater than or equal to 124 micron. Therefore, commonly used clinical evaluation techniques using an explorer and disclosing media may be inadequate for assessments of marginal accuracy.

Soriani *et al.*,^[25] evaluated the effect of using die spacers on the marginal fit of NiCr (M1) and NiCrBe (M2) alloys and commercially pure titanium (cpTi) (M3) copings cast by the lost wax technique. Using a metal matrix, 45 resin added extra hard type IV stone models were obtained for the fabrication of wax patterns under the following conditions: No die spacer (A), with one die spacer layer (B) and with two die spacer layers (C), with five repetitions for each condition (alloy x die). Each die was waxed and the wax patterns were invested as per manufacturer's instructions. It was concluded that there is less marginal discrepancy with two die spacer layers.

Rathod and Chitnis^[26] investigated and compared the validity of ringless investing-system for marginal fit of the copings and the conventional-metal ring-investing system. To standardize the study, 40 copings were directly fabricated on a metal die (maxillary premolar) and were segregated into two main groups. Group I ($n = 20$) were invested with conventional metal-ring-investing system and Group II ($n = 20$) were invested in with ringless system. Marginal discrepancy of the copings was measured at

the four surfaces (buccal, palatal, mesial, and distal) with an optical microscope (Nikon Maesuroscope model) in microns (μ). The result showed that the vertical marginal discrepancy of the ringless group for buccal, palatal, mesial, and distal sites were significantly less than that of conventional-metal-ring-investing system.

Lee *et al.*,^[27] have also explored about the marginal and internal fit of all-ceramic crowns fabricated with two different computer-aided design/computer-aided manufacturing (CAD/CAM) systems. They evaluated the accuracy of marginal and internal fit between the all-ceramic crowns manufactured by a conventional double-layer CAD/CAM system and a single-layer system. Ten standardized crowns were fabricated from each of these two systems: Conventional double-layer CAD/CAM system (Procera) and a single-layer system (Cerec 3D). The copings and completed crowns were seated on the abutments by a special device that facilitated uniform loading, and the marginal discrepancies were measured. On internal gaps, Cerec 3D crowns showed significantly larger internal gaps than Procera copings and crowns ($P < 0.05$). Within the limitations of this study, the single-layer system demonstrated acceptable marginal and internal fit.

Oyagüe *et al.*,^[28] worked well to evaluate the influence of the alloy type and the associated investing and casting techniques, on the marginal adaptation of bridge structures luted onto prefabricated implant abutments. Their study clearly showed that the vertical fit of the frameworks cast for implant-cemented bridges was influenced by the alloy type and the investing and casting methods. The marginal discrepancy of the three alloys tested could be considered clinically acceptable. A polished technique in the management of titanium could optimize the accuracy of these cast frameworks. Örtorp *et al.*,^[29] further investigated this issue in one of their study evaluating the marginal and internal fit *in vitro* of three-unit Fixed Partial Dentures in Co-Cr made using four fabrication techniques. A total of 32 three-unit Co-Cr FPDs were fabricated with four different production techniques: Conventional lost-wax method (LW), milled wax with lost-wax method (MW), milled Co-Cr (MC), and direct laser metal sintering (DLMS). Each of the four groups consisted of eight FPDs (test groups). The FPDs were cemented on their cast and standardized-sectioned. The cement film thickness of the marginal and internal gaps was measured in a stereomicroscope and digital photos. Best fit was found in the DLMS group followed by MW, LW, and MC. In all four groups, best fit in both abutments was along the axial walls and in the deepest part of the chamfer preparation.

Barbi *et al.*,^[30] further explained this dilemma in their study that was actually aimed to access different joining techniques that could improve the passive fit of cobalt-chromium superstructures. A specially designed metal model was used

for casting, sectioning, joining, and measuring marginal misfit. The method used for joining Co-Cr prosthetic structures had an influence on the level of resulting passive fit. Structures joined by the tungsten inert gas method produced better mean results than did the brazing or laser method.

In a very recent study conducted by Regish *et al.*,^[31] evaluation and comparison of the internal fit and marginal accuracy of base metal (nickel chromium) and zirconia copings before and after ceramic veneering was completed successfully using scanning electron microscope. A standardized metal master die simulating a prepared crown was fabricated and twenty impressions of the metal die were made and poured with die stone. Wax patterns were made on 10 dies and cast, while light-cure resin patterns were made on the other 10 dies for copy milling the zirconia copings. Five specimens from each group were subjected to ceramic veneering. All the test specimens were luted on to the fresh dies, embedded in dental plaster, sectioned, and image analysis done using scanning electron microscopy. The internal fit and marginal adaptability of Ni-Cr copings were found to be better than the copy milled zirconia copings but internal fit and marginal adaptability deteriorated after ceramic veneering.

Gómez-Cogolludo *et al.*,^[32] have also explored the effect of electric arc, gas oxygen torch, and induction melting techniques on the marginal accuracy of cast base-metal and noble metal-ceramic crowns. The Ni-Cr-Ti alloy was the most predictable in terms of differences in misfit when either torch or induction was applied before or after cementation. Cemented titanium crowns exceeded the clinically acceptable limit of 120 μ m. They concluded that the combination of alloy composition, melting technique, casting method, and luting process influences the vertical seal of cast metal-ceramic crowns. An accurate use of the gas oxygen torch may overcome the results attained with the induction system concerning the marginal adaptation of fixed dental prostheses.

III - Review related to casting and investment technique

Cooney *et al.*,^[33] evaluated two phosphate-bonded investment materials and one calcium sulfate investment materials for surface smoothness and fit of the casting obtained. A modified technique for phosphate-bonded investment was also tested, where silica solution was not diluted and the spatulation time was reduced. They concluded that the marginal fits obtained with all four phosphate bonded investments were comparable to each other and the calcium sulfate investment produced greatest marginal openings. He also concluded that there was no correlation was demonstrated between surface roughness and marginal fit of the castings. Lacy *et al.*,^[34] evaluated the three factors which affect the investment setting expansion and casting size. They recognized the major variables of casting as number of liners in the ring, position of liners,

position of wax pattern in the ring, and water/powder ratio of investments; and they conducted a study to evaluate the effect of a) mixing rate, b). ring liner position, and c) storage condition on the setting expansion of both gypsum-bonded and phosphate-bonded investment molds and subsequently relate casting size with measured expansion data. They concluded from their study that the setting expansion was the least with no ring liner and the greatest with a full liner which allowed for no restriction of the investment material. They also concluded that the phosphate-bonded investment material showed overall greater setting expansion than gypsum-bonded investment for the same ring/liner/mix mode configuration and the dynamic nature of setting expansion within the first 60 min after mixing suggested that consistent results can be obtained by waiting for at least that long prior to burn out.

Dean *et al.*,^[35] studied the effect of two-step ringless investment technique on alloy castability. The purpose of their study was to evaluate the effect of two-step ringless partial denture investment technique on castability of a base metal crowns and fixed partial denture alloys. They took one control group casting of ceramigold investment vacuum mixed and an experimental group consisting of ceramigold investment vacuum mixed. Immediately after initial set of vacuum mixed, another mix which was hand whipped for 45 s filled in a similar manner as control. Castability values were obtained for 60 test patterns on two different casting units at two different mold temperatures 1250° F and 1500° F. No significant differences were found between the control technique and experimental techniques at the same mold temperature. However, significant difference was found between castings made by the two casting units at a temperature of 1250° F. Ito *et al.*,^[36] evaluated the relationship between flow characteristics, bending strength, and softening temperature of paraffin and dental inlay waxes to casting shrinkage when patterns were invested with a phosphate-bonded investment. This study found that the casting shrinkage decreased as the flow of the wax pattern increased. If a low flow wax is used or if there is a need for a thick pattern, the size of the casting ring should be increased. When wax patterns are formed for cast restorations, it is important to select the type of wax with the most desirable properties for the margin and the occlusal portions. Moreover, to accurately fabricate castings, it is necessary to understand the physical properties of the chosen waxes. On the contrary, Takahashi *et al.*,^[37] and associates developed a new device for measuring the setting expansion of phosphate-bonded investment and assessed the effect of different pattern materials on the internal setting expansion. Three pattern materials were soft inlay wax, hard inlay wax, and autopolymerizing resin. Standard crown type patterns were prepared for all the materials on a custom-designed metal die and invested patterns were subjected to testing. The results of their study show that both horizontal and vertical setting expansions inside a pattern invested in a casting ring were nonuniform, of which horizontal expansion was more irregular for all

the three materials, leading to the distortion of the patterns. Among the three pattern materials, soft wax had the minimum nonuniformity, and resin had the maximum nonuniformity. Schilling *et al.*,^[38] conducted a *in vitro* study to evaluate marginal gap of crowns made with a phosphate-bonded investment and accelerated casting technique. From this study, they concluded that the marginal gaps for casting made with an accelerated technique showed no statistical differences when compared with the conventional casting group. The accelerated casting technique offers a cost-effective and time saving method by which single-unit casting for metal or ceramic crowns can be fabricated.

In another study, Lombardas *et al.*,^[6] evaluated the dimensional accuracy of castings produced with ringless and metal ring investment systems. On a metal die, 30 copings were made and divided into three groups of 10 copings. For the first and third groups metal ring was used for investing and casting. In the first group, metal ring with 2.5 cm diameter and a ceramic line paper (Bego) which was wetted for 1 min used. In the third group, metal ring along with ceramic paper liner (Bego) was used according to manufacturer's instruction, whereas for the second group, a ringless system was used. The copings were seated on the metal die and accuracy of fit was evaluated by measuring the gap between the finish line and margins of the copings on four sites with the use of an optical microscope under 100 (×). They concluded that the vertical marginal discrepancy of the ringless groups were significantly less than that of the two with rings groups. There were no significant differences of the vertical marginal discrepancy between the two metal ring groups. Gill^[39] analyzed the marginal gap of complete crowns made by using wet and dry ceramic liners. Their results demonstrated that the castings made with dry ceramic ring liners exhibited a lower mean marginal gap (54.5 µms) as compared with those made with wet ceramic ring liner (153.0 µms). This difference was statistically highly significant ($P < 0.001$). Therefore, he concluded that in order to obtain castings with a lesser marginal gap, dry ceramic ring liner better than a wet ceramic ring liner. Shah *et al.*,^[40] conducted an *in vitro* study to compare the vertical marginal accuracy of single full coverage metal restorations, between ring-less and metal ring investment techniques, using two different types of phosphate-bonded investment materials, for implant supported fixed dental prosthesis. Three groups were made of ten samples each. Group I consisted of a metal ring with PCT Flex Vest (phosphate bonded investment material). Group II consisted of a metal ring with Bellasun phosphate-bonded investment material. Group III consisted of a ring-less investment system and Bellasun investment material. The wax patterns were prepared on a metal die, cast, and finished. The cast restorations (samples) were again seated on the metal die and the accuracy of fit was evaluated by measuring the gap between the finish line on the die and the margins of the sample at four specific sites using a profile projector (Helios-350H, Microtecnica,

LTE, Italy) having accuracy of 1 micron. The result of the study showed that mean marginal accuracy for Group III was found to be the least ($58.87 \pm 17.87 \mu\text{m}$) followed by Group II ($97.23 \pm 16.37 \mu\text{m}$), and Group-I ($109 \pm 7.55 \mu\text{m}$). They concluded that ring-less system of casting can be recommended for use in fabricating implant-supported fixed dental restorations.

Discussion and conclusive remarks

Over the years, various cast metals and alloys have been used for fabrication of fixed ceramometal prosthesis. The use of gold for restorations has been reported as early as 1907 along with introduction of the lost wax technique.^[6] Alloys with high gold content are found to produce excellent esthetic and functional results when used for ceramometal restorations. Marginal fit is one of the most important factors for the success of any restoration.^[39] Retention of plaque can lead to both marginal inflammation as well as gingival recession. Insufficient marginal fit can cause caries and secondary caries below the margins of the crown, thus; vertical and lateral deficiencies at the margins of restorations often lead to periodontal breakdown resulting in tooth loss.^[41]

The marginal accuracy of cast restorations is affected by clinical and laboratory factors like the quality of preparation, undercuts, finish line location, final impression, the working cast, thickness of die spacer, the quality of the wax used for the lost wax technique, appropriate compensation for the casting shrinkage of the alloy used, sprue configuration and design, thickness of casting ring, thickness of ring liner, casting armamentarium used, type of cement and luting pressure applied, surface roughness, and irregularities of cast restorations.^[6] Since the fit is dependent on so many factors, it is mandatory to follow sound production for fabrication of accurately fit castings.^[35] Ringless casting technique is a routinely used procedure for both conventional fixed prosthodontics and implant prosthodontics,^[6] the main factors contributing toward marginal integrity are the castability and casting shrinkage of the nickel-chromium alloy and this must be partially compensated by the casting technique if a precise fit is desired. Although the metal ring technique is clinically acceptable and allows for the fabrication of accurate castings, the metal ring restricts the setting and thermal expansion of the investment which is necessary to compensate for the shrinkage of the metal on solidification.^[7] To overcome this expansion restriction, a soft liner is used to avoid the restriction of setting and thermal expansion associated with the presence of metal ring.^[6,42] Metal ring restricts the setting and thermal expansion of the investment which is necessary to compensate for the shrinkage of the metal on solidification.^[3,14,16] The compensation for the shrinkage inherent in the dental casting procedure may be obtained by either one or both, that is, setting or hygroscopic expansion of the investment and the thermal expansion of the investment. Phosphate-bonded investment materials are commonly used for modern day castings and consist

essentially of two main groups of ingredients, fillers and binders. The fillers usually consist of quartz and/or cristobalite. Apparently, the fillers play a very small role in controlling the chemistry of the investments. The binders are essentially basic MgO and acidic $\text{NH}_4 \text{H}_2 \text{PO}_4$.^[43] The main advantage of these phosphate-bonded investment material is high heat tolerance, adequacy of investment expansion to compensate for casting shrinkage, ease of casting retrieval from the fired high strength investment, and the material ability to obtain complete, nonporous castings which minimizes the casting defects was used.^[17]

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