Dimensional Accuracy of Castings Fabricated with Ring-less and Metal Ring Investment Systems for Implant Supported Fixed Dental Prosthesis : An In-vitro Comparative Study

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Abstract

Background: The ring-less investment system is in use for dental casting, although there was no adequate scientific data to support its use either for conventional fixed dental prosthesis or implant retained fixed dental prosthesis.

Methods: An in-vitro study was undertaken to compare the vertical marginal accuracy of single full coverage metal restorations, between ring-less and metal ring investment techniques, using two different investment materials, for implant supported fixed dental prosthesis. Three groups were made of ten samples each. Group I consisted of metal ring with PCT[®] FlexVest (phosphate bonded investment material). Group II consisted of metal ring with Bellasun[®] investment material. Group III and the final group consisted of 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, LTF, Italy) having accuracy of 1µm.

Result: 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 ($109 \pm 7.55 \mu\text{m}$). However, Group I showed the least variability among the readings ($\text{SD}=7.55$).

Conclusion: Ring-less system of casting can be recommended for use in fabricating implant supported fixed dental restorations.

MJAFI 2011; 67 : 46-51

Key Words : Ring-less investment system; Dental casting; Marginal accuracy; Implant supported fixed dental prosthesis

Introduction

The concept of inducing controlled interfacial osteogenesis between titanium dental implants and the host bone was introduced by Dr. Per Ingvar Branemark in 1982 at the Toronto Conference. Since then, rehabilitation of partially and completely edentulous patients using dental implants has become a predictable therapeutic procedure [1].

Peri-implant soft tissue health will be adversely affected by the magnitude of marginal gaps. Therefore, marginal fit of different types of dental implant crowns is a critical area of dental research [2,3]. Keith et al [4] in 1999 compared the in-vitro marginal discrepancies between cement and screw retained implant crowns. They found that screw retained crowns had statistically significant smaller marginal gaps compared with cement retained crowns.

The base metal alloys, due to higher melting temperatures compared to precious metal alloys, require the use of silica based investments which can withstand

high temperature. The addition of silica reduces the compressive strength and makes the use of a metal ring necessary to protect the investment during casting process [5]. The metal casting ring restricts the thermal expansion of the investment because the thermal expansion of the ring is less than that of the investment. The use of the casting ring for the phosphate bonded investments was not questioned because its use was a standard procedure [6]. This was challenged with the introduction of a ring-less technique initially for removable partial denture frameworks [7] and recently, for conventional fixed restorations [8]. High strength of the investment material makes it possible to cast without the ring. The ring-less technique is easier, inexpensive, and is believed to produce clinically acceptable castings. In the literature, there are very few studies on ring-less casting technique for fixed restoration, and there is not enough evidence to support the assumption that the ring-less casting technique can produce accurate castings [9]. Though the casting with metal ring is a reliable and

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time-tested technique which produces clinically acceptable marginal accuracy, there is a positive restriction on the expansion of mould due to the ring. It is worth investigating whether the ring-less technique can be employed routinely to produce accurate castings for fixed partial dentures by eliminating the need of using the metal ring which might be having a restrictive influence on the expansion of mould.

Material and Methods

An in-vitro study was undertaken to compare the vertical marginal accuracy of single full coverage metal restorations, between ring-less and metal ring investment techniques, using two different investment materials, for implant supported fixed dental prosthesis. Three groups were made of ten samples each. Group I consisted of metal ring with PCT® Flex Vest (phosphate bonded investment material). Group II consisted of metal ring with Bella sun® investment material. Group III consisted of ring-less investment system and Bella sun® 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, LTF, Italy) having accuracy of 1µm.

A stainless steel metal die simulating single piece dental implant was prepared using laser cutting. Shape of implant was threaded, parallel side solid cylindrical of 12 mm length and 03 mm diameter. Shape of abutment was a tapered cone having length of 6.5 mm, diameter of 4.8 mm in cervical region and 3.5 mm occlusally with 4° taper. Margin of the abutment was kept 0.5 mm wide and 30° sloping shoulder along with two opposing flat surfaces as anti-rotational feature. The metal die was mounted on to an acrylic block. Orientation guides in the form of two rectangular and two triangular depressions were prepared on the superior surface of the acrylic block. A wax pattern of the shape of a tapered cone with approximate width of 1mm was prepared using Kronenwachs® (BEGO, Bremen, Germany) and remargination was carried out using Cervikalwachs® (BEGO, Bremen, Germany). Wax pattern was then sprued and invested in a metal ring with single layer of wet cellulose acetate ring liner, using carbon free phosphate bonded investment material PCT® FlexVest (Ivoclar Vivadent, Liechtenstein, Italy). Burnout of the wax pattern and casting was carried out in a conventional manner using burn-out furnace MIDITHERM-100AN® (BEGO, Bremen, Germany) and induction casting machine FORNAX 35E® (BEGO, Bremen, Germany) respectively. Ni-Cr alloy - Wirrolloy® (BEGO, Bremen, Germany) was used for casting of metal coping/ space former. The finished metal coping thus obtained was then kept on the metal die (mounted on acrylic block) on which wax pattern was fabricated. A vertically split putty mould was obtained by using two separate pours of Vinyl Polysiloxane impression material-EliteH-D+® (Zhermack, Badia Polesine, Italy) with a layer of petroleum jelly over the first pour. Split putty mould

thus created was checked for the accuracy of impression of metal coping placed on the metal die. The metal coping was then removed from the metal die and split mould was placed back on the acrylic block (Fig. 1). A uniform space was thereby created for wax pattern fabrication for subsequent standardized samples. Molten blue inlay wax- Kronenwachs® (BEGO, Bremen, Germany) was poured into the mould with continuous tapping. After the setting of molten wax the split putty mould was separated and the wax pattern checked for complete flow of molten wax. Wax patterns with any deficiencies were discarded. Remargination of wax pattern (cervical 1 mm) was carried out using pink inlay marginal wax - Cervikalwachs® (BEGO, Bremen, Germany). Thirty patterns were fabricated and divided into 3 groups (Group I, II and III) of 10 patterns each. Group I included metal ring investment system with single layer of cellulose acetate ring liner and carbon free phosphate bonded investment material PCT® FlexVest (Ivoclar Vivadent, Liechtenstein, Italy). Group II was same as Group I except that the investment material used was carbon free phosphate bonded investment Bellasun®, BEGO, Bremen, Germany). A ring-less investment system Thermofix 2000® (Dental Future System, Riedenburg, Germany) with carbon free phosphate bonded investment Bellasun® (BEGO, Bremen, Germany) was used for group III for investing and casting procedures.

A preformed sprue wire of 3 mm diameter and 15 mm length was used for spruing. The patterns were sprued at the occlusal level of wax pattern at an angle of 45°. A reservoir in the shape of a bead of wax was attached about 5 mm away from the pattern. The highest point of the pattern was kept approximately 6 mm below the open end of the casting ring so as to allow escape of gases during burnout stage and prevent fracture of investment due to impact of molten metal during casting process. All sharp junctions were eliminated by suitable addition of casting wax to avoid any turbulence in the molten alloy during the filling of the mould. The sprued patterns were carefully weighed in order to calculate the number of alloy ingots required for casting. Metal rings of size 3x and lined with single layer of asbestos free cellulose acetate liner were used for investing wax patterns of group I and II (Fig. 2). For Group III instead of metal ring, a ring-less system - Thermofix 2000® (Dental Future System, Riedenburg, Germany) 3x size was used (Fig. 3). The system had a thermal sensor strip on the external surface that consisted of three circular markings 1, 2 and 3 starting from inferior surface. The changes in color from yellow, red, green, blue and finally black with increase in temperature indicated the progress of setting of the investment material. The sprued pattern was attached to the base former and the casting ring was then placed over it. Carbon free phosphate bonded investment material PCT® FlexVest (Ivoclar Vivadent, Liechtenstein, Italy) and Bellasun® (BEGO, Bremen, Germany) were used for group I and II respectively. The investment material provides a total expansion of 2.5 % when mixed with 100% special expansion liquid PCT® FlexVest (Ivoclar Vivadent, Liechtenstein, Italy) and Begosol® (BEGO, Bremen, Germany) where as casting of alloy (as claimed by manufacturer) was around 2%. Therefore, the special expansion liquid was diluted to a concentration of

80% with distilled water. The recommended powder liquid ratio of 100 gm : 23 ml was used. The powder and liquid were carefully hand mixed in a clean rubber bowl using clean spatula for 15 seconds until the investment was uniformly moist with no lumps. The investment was then thoroughly mixed using a vacuum mixing unit Motova® (BEGO, Bremen, Germany) for 90 seconds as recommended by the manufacturer. Surface tension reducing agent Aurofilm® (BEGO, Bremen, Germany) was sprayed onto the wax pattern and allowed to dry. The mixed investment was first carefully applied to the pattern with a brush and then the investment material was vibrated into the casting ring placed on a bench vibrator Vibroboy® (BEGO, Bremen, Germany) till it was filled to the top. The investment rings were allowed to set undisturbed for 60 minutes. For Group III the moulds were removed from the ring after initial setting of investment material (Fig. 3) that was indicated by change in color of No. 3 circle back to black (approximately ten minutes). Single wax pattern was invested at a time and processed so as to standardize the thickness of investment surrounding wax patterns. Silicone base former was removed after 60 minutes of set at room temperature. The mould / ring was then placed in the burnout furnace MIDITHERM-100AN® (BEGO, Bremen, Germany) at room temperature. The temperature of furnace was gradually increased from room temperature to 270°C with

Fig. 1 : Split putty mould after removal of metal coping.

Fig. 2 : Spruing of wax pattern using metal casting ring lined with single layer of cellulose acetate ring liner. (A) Frontal view (B) Superior view. Used for fabricating first metal coping as well as samples of Group I and Group II.

holding time of 30 minutes, from 270°C to 560°C with holding time of 20 minutes and from 560°C to final temperature of 1040°C with holding time of 45 minutes at maximum temperature. To reduce the time lag between melting of alloy and casting, the crucible with the ingots of the alloy was preheated in the burnout furnace. Nickel-Chromium metal casting alloy Wiroloy® (BEGO, Bremen, Germany) was used for casting. The moulds / casting rings were allowed to bench cool to room temperature before divesting from the investment. The remaining adherent investment was removed by sandblasting with 250 µm aluminum oxide in Korostar Z® (BEGO, Bremen, Germany) sandblasting unit followed by steam cleaning using steam cleaner Triton SLA® (BEGO, Bremen, Germany). The sprue was removed using high speed cut-off discs. Castings were examined under magnification and proper illumination. Isolated nodules were removed using sintered diamond burs and stones. The castings were finished minimally. The inner surface of the castings was not touched at all.

Predetermined areas 90° apart were marked as position A, B, C and D on the acrylic block on which the metal die was mounted. The casting was seated on the metal die with finger pressure. The equipment used for measuring the vertical marginal accuracy was profile projector (Helios-350H® Microtecnica, LTF, Italy) for accuracy of measurement (01 µm) at 10x magnification (Fig. 4).

Fig. 3 : Ring-less investment system; removal of plastic ring after initial set of investment material.

Fig. 4 : (A) Close up view of projection for marginal evaluation (B) Electronic monitor showing readings along X-axis and Y-axis.

Results

Results obtained were tabulated and subjected to statistical analysis. Table 1 is a summary table which shows that average marginal discrepancy was minimal for location “C” followed by “B”, “D” and “A”. As regard the groups, Group-III generated the least marginal discrepancy followed by Group-II and Group-I. However, the Group-I had the least variability ($SD = 7.55$). Since the interest lies in determining if the three groups differ significantly from one another with respect to mean discrepancy over all four locations, Multivariate Analysis of Variance (MANOVA) with multiple observations was carried out. The results of MANOVA were presented in Table 2. Starred values in Table 2 suggest that groups differ significantly with respect to the overall mean marginal discrepancy, by all the four test criteria. The p-values were < 0.0001 in each case which implies that mean differences were very highly significant. To see, if the group differences were statistically significant from location to location, one-way ANOVA was also applied for each location. The results

of this analysis were presented in Table 3 which shows that Test value F is significant for each location. Since p-values are < 0.0030 in all cases, the mean differences among the groups were very highly significant from location to location also. Multiple comparisons had been made by using Tukey’s honest significant difference (Tukey’s HSD) (Table 4) test as this is an exact test and therefore provides more accurate results. For location “A”, the Group I and Group II do not differ significantly but both Group I and Group II differ significantly from Group III (p-values 0.0001 and 0.0010 respectively). This means that ring-less casting system produced significantly low marginal discrepancy with respect to this location. The results were identical for location ‘B’ and location ‘D’. For location ‘C’, there was no significant difference between Group I and Group II situation, which was same between Group II and III. However the difference between Group I and Group III (p-value 0.0030) was again significant.

Table 1
Mean $\pm$ SD

Group	Location				Average
	A	B	C	D	
I	117.70 $\pm$ 31.97	97.63 $\pm$ 28.46	94.87 $\pm$ 17.02	126.73 $\pm$ 6.29	109.23 $\pm$ 7.55
II	114.67 $\pm$ 33.95	96.13 $\pm$ 22.93	80.03 $\pm$ 8.75	98.10 $\pm$ 41.07	97.23 $\pm$ 16.37
III	57.40 $\pm$ 22.36	57.17 $\pm$ 27.74	65.87 $\pm$ 23.93	55.03 $\pm$ 25.41	58.87 $\pm$ 17.87
Average	96.59 $\pm$ 33.97	83.64 $\pm$ 22.94	80.26 $\pm$ 14.50	89.33 $\pm$ 36.09	

All readings are in μm .

Table 2
Multivariate analysis of variance (MANOVA)

Effect	Test	Value	F	Hypothesis df	Error df	Significance p-value
Groups	Pillai’s Trace	0.834	4.468*	8	50	0.0001
	Wilks’ Lambda	0.250	6.000*	8	48	0.0001
	Hotelling’s Trace	2.665	7.663*	8	46	0.0001
	Roy’s Largest Root	2.533	15.832*	4	25	0.0001

*Groups differ significantly with respect to the overall mean marginal discrepancy by all four test criteria.

Table 3
Tests of between-subjects effects (One-way ANOVA)

Source	Dependent variable	Sum of Squares	df	Mean Square	F	Significance p-value
Groups	Location-A	23082.541	2	11541.270	12.941*	0.0001
	Location-B	10527.341	2	5263.670	7.298*	0.0030
	Location-C	4205.741	2	2102.870	6.662*	0.0040
	Location-D	26051.652	2	13025.826	11.282*	0.0001
Error	Location-A	24078.722	27	891.805		
	Location-B	19473.311	27	721.234		
	Location-C	8523.078	27	315.670		
	Location-D	31173.622	27	1154.579		
Total	Location-A	47161.263	29			
	Location-B	30000.652	29			
	Location-C	12728.819	29			
	Location-D	57225.274	29			

Table 4**Multiple comparisons using Tukey's honest significant difference (Tukey's HSD) test**

Dependent variable	Test criterion	Group (I)	Group (J)	Mean difference (I-J)	Std. Error	Significance p-value
Location-A	Tukey HSD	I	II	3.0333	13.3552	0.9720
			III	60.3000*	13.3552	0.0001
			II	57.2667*	13.3552	0.0010
Location-B	Tukey HSD	I	II	1.5000	12.0103	0.9910
			III	40.4667*	12.0103	0.0060
			II	38.9667*	12.0103	0.0090
Location-C	Tukey HSD	I	II	14.8333	7.9457	0.1680
			III	29.0000*	7.9457	0.0030
			II	14.1667	7.9457	0.1940
Location-D	Tukey HSD	I	II	28.6333	15.1959	0.1630
			III	71.7000*	15.1959	0.0001
			II	43.0667*	15.1959	0.0230

Discussion

Marginal fit is influenced by several factors including type of crown, tooth preparation geometry, dimensional accuracy of impression materials, factors related to dental casting, type of cement, luting pressure, duration of cementation and use of occlusal vents or die spacers [10]. However, there is no clear evidence that one crown type or method of casting provides consistently superior marginal fit.

The metal ring casting technique is well documented in the literature. Studies have shown that casting ring shape, diameter and length affect the accuracy of castings produced because these may influence the expansion of the investment. Although it produces clinically acceptable results, 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. To overcome this restriction on expansion, a soft liner is used. There is a lot of controversy regarding the method of use of the ring liner. Some researchers advocate the use of wet liner whereas others advise dry liner. Few prefer one layer of liner while others insist double layer. While some authors recommend flushing of the liner with the ring ends, many investigators prefer to keep it short. Though everybody justifies the use of their method the fact remains that all these factors may affect the casting accuracy. Use of a ring-less system will eliminate all these variables as discussed above and it will be easier to produce more accurate castings. The ring-less technique for investing and casting has been in use for many years for the fabrication of frameworks for removable partial dentures. It was introduced in fixed prosthodontics on the premise that the restrictive influence of the metal ring on setting and thermal expansion of mould would be avoided but there is dearth of literature supporting

the use of this technique in implant prosthodontics.

In present study, the vertical marginal accuracy of castings fabricated with ring-less system (Group III) was found to be statistically significantly high ($p < 0.0001$). The decreasing order of accuracy of fit of castings among three groups was Group III > Group II > Group I. This can be explained on the ground that in this technique, complete expansion of the mould during setting of the investment occurred uniformly in all directions without any restriction. The setting expansion was also not restricted as the plastic ring was opened up immediately on initial set of the investment. Mitchell et al [10] cited their article reference to 120 μm representing the maximum clinically acceptable marginal gap. The results of all three groups in this study fell into this range. It was also observed that none of the moulds of ring-less technique either cracked or fractured on its own and during or after the casting despite the absence of the metal ring. This proves that this system can be safely used for predictable casting.

Within the limitations of this study it could be concluded that the vertical marginal accuracy of castings fabricated with ring-less system (Group III) was found to be statistically highly significant ($p < 0.0001$). The castings fabricated using metal ring showed more consistent type of results compared to restorations fabricated using ring-less system. Therefore, from the present study, ring-less system of casting can be recommended for use in fabricating implant supported fixed dental restorations. However, further studies should be carried out with increased number of samples, wider range of investment materials / systems and more number of locations for measurements to substantiate these results.

Conflicts of Interest

None identified.

Intellectual Contribution of Authors

Study Concept : Maj Rakesh Shah

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Book Review

Total Hip Replacement (Principles and Techniques). Marya SKS, Bawari RK. Publisher: Jaypee Brothers Medical Publishers (P) Ltd. Pages: 155; Hardbound, Year of Publication: 2010. First Edition. ISBN: 978-81-8448-884-5.

When reviewing the first edition of any book, one has to identify the niche area/gaps in available literature that the book aims to fill. This book is aimed at Indian orthopedic surgeons who are at the beginner level in learning skills of total hip replacement which is increasingly becoming a relatively common surgical procedure in India.

The authors have simplified the hip anatomy and relevant biomechanics adequately to be understood easily. The section on preoperative planning is quite useful, especially the stress on hip scoring as well as consent. Templating and its importance are quite well brought out.

However, though the book is aimed only at beginners, the authors take a far too simplistic approach to a fairly complicated procedure. While discussing the implant choices, the authors aim to keep the discussion simple but, in the process, they end up confusing the beginner rather than helping him to make an informed choice about implant preference in a given clinical situation. Some of the illustrations used to show specific implants actually show implants in unacceptable position (e.g. Acetabular cup position in Metal on metal bearing in Fig 2.1, page 12). Quite a few of the described techniques are outdated, e.g. cement pressurization in femur as well as acetabulum has been skipped, use of burrs while broaching for small femur size has been recommended etc.

The postoperative management described by the authors is also quite controversial. The antibiotic prophylaxis duration (up to 7th

post-op day), thromboprophylaxis regime (uniformly applied for all cases rather than currently recommended risk stratified) and transfusion indications (Hb less than 10 gm %) recommended by the authors are quite outdated, contrary to current evidence and could be dangerous in some situations. The recommended exercises and patient positioning advice could have been more specific.

A textbook aimed at beginners would have been really useful if it had included complications/ problems expected at each step and ways to avoid them. For example, the authors specify the ideal position for acetabular cup repeatedly but don't offer any tips to achieve this position. The specific problems/ issues faced in various hip pathologies do not even find a mention. A chapter on the problems faced while dealing with various specific pathologies would have been very helpful, e.g. Rheumatoid arthritis, ankylosing spondylitis, hip arthroplasty in the relatively young, Avascular necrosis, protrusio acetabuli, osteoporosis, hip dysplasia etc.

To conclude, this book, especially the live surgery videos available with the book, may be a supplement to the beginners but remains quite inadequate and incomplete as the only reference. The authors have even failed to provide any references for any of their material and have not recommended any further reading material. Even the hip arthroplasty chapter of "Campbell's Operative Orthopaedics" provides much more information about hip arthroplasty than this book.

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