Research Article

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Comparison of Dimensional Accuracy of Casting Produced with Ringless and Metal Ring Investment Systems: An In Vitro Study

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ABSTRACT

Background: The accuracy of fit of a cast restoration is essential for its longevity because it provides better mechanical properties (retention, resistance), less cement space (less possibilities for cement leakage and recurrent caries) and improves the esthetic result. In literature, there are few studies to support the assumption that the ringless casting technique can produce accurate castings. Therefore, this study was undertaken to compare the marginal accuracy of all metal complete coverage crown fabricated with ringless, metal, dry cellulose liner and wet cellulose liner technique of investing and casting.

Material and Methods: Total 50 wax patterns were fabricated over the metal die and divided into five groups. Casting produced with Deguvest impact investment material and Biosint extra investment material with metal ring technique and ringless technique.

Results: Result of the present study revealed that the castings produced by ringless technique fits better than the castings produced by using the conventional metal ring technique.

Conclusion: Ringless technique with deguvest impact investment material showed less vertical marginal discrepancy than ringless technique with biosint extra investment material. The casting produced by metal ring technique with deguvest impact investment material showed more accurate casting and less vertical marginal discrepancy than the castings produced by metal ring technique with biosint extra investment material.

Keywords: Dimensional accuracy, Ringless technique, Metal ring technique, Investment material, Casting.

INTRODUCTION

All metal complete coverage crown is one of the most commonly indicated and routinely fabricated restoration in fixed prosthodontics. Accuracy of the marginal fit, configuration and location of finish line are important in the clinical acceptability of crowns to satisfy biological, physical, mechanical and esthetic requirements[1]. It is essential to achieve compensation for the shrinkage of the solidifying alloys by the investment. 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[2]. In literature there are few studies to support the assumption that the ringless casting technique can produce accurate castings. Therefore, this study was undertaken to compare the marginal accuracy of all metal complete coverage crown fabricated with

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ringless, metal, dry cellulose liner and wet cellulose liner technique of investing and casting.

MATERIALS AND METHOD

1. Metal die preparation:

A custom made stainless steel die was prepared to simulate for Right 1st maxillary molar having uniform heavy chamfer finish line (0.8 mm wide) taper of proximal wall is 6 degree. This metal die was mounted in dental stone for stabilization.

2. Fabrication of all metal coverage crown:

For the fabrication of wax copings two coats of Cerestore die spacers provided 25 microns thickness was applied with the brush over the metal die which was1mm short of margin. A wax pattern of width of 1 mm was prepared with pattern wax (bego Germany). Than the margin is remelted with PKT no.1. Than the cervical wax is added to the margin with a beavertail burnisher and excess wax is removed with a PKT no.4. Than margins are finished with a beavertail burnisher.Total 50 wax patterns were fabricated over the metal die and divided into five groups A, B, C, D, and E.

GROUPS	TECHNIQUE USED FOR INVESTING
GROUP A	DEGUVEST IMPACT investment material with ringless technique
GROUP B	DEGUVEST IMPACT investment material with metal ring using dry cellulose ring liner
GROUP C	BIOSINT EXTRA investment material with ringless technique
GROUP D	DEGUVEST IMPACT investment material with metal ring using wet cellulose ring liner
GROUP E	BIOSINT EXTRA investment material with metal ring technique

3. Investing:

I. In Group A investing was done in a deguvest impact (phosphate bonded crown and bridge investment material DENTSPLY) with a ringless technique using the ringless ring former (bego Germany). Investment mixing ratio of 100g: 23ml powder: liquid was used according to manufacturer recommendations. First the mix is hand spatulated to incorporate powder quickly then the investment is vacuum mixed in CUUMYX (LABO-14). Now pattern is coated with investment pushing the material ahead of the brush from a single point. The application to coat internal surface was done with care. After the pattern was completely coated the ring is immediately filled with investment. The ring was filled slowly from the bottom to above. Now investmentring was allowed to set undisturbed for 60 minutes.

II. In Group B investing was done in deguvest impact investment material using dry cellulose ring liner. Investment mixing ratio of 100g: 23ml powder: liquid was used according to manufacturer recommendations. In dry cellulose technique the dry liner is tacked in position with a sticky wax and then the liner is used. Rest all procedure of investing was same as described for group A.

III. In Group C investing was done in biosint extra investment material using ringless technique. Investment mixing ratio of 100g: 15ml powder: liquid was used according to manufacturer recommendations. Rest all procedure of investing was same as described for group A.

IV. In Group D invested in deguvest impact investment material using wet cellulose ring liner. Investment mixing ratio of 100g: 23ml powder: liquid was used according to manufacturer recommendations. With a wet liner technique, the lining ring is immersed in water for a time, and excess water is shaken away. Squeezing the liner should be avoided because this lead to variable amount of water removal and uneven expansion. Rest all procedure of investing was same as described for group A.

V. In group E investing was done in a biosint extra (the plaster free phosphate bonded investment material for partial dental work) investment material using conventional metal ring technique. Investment mixing ratio of 100g: 15ml powder: liquid is used according to manufacture recommendation. Rest all procedure of investing was same as described for group A.

4. Casting procedure:

The ring was placed in the burnout furnace at room temperature and heated to815 degree Celsius in one hour. It is allowed to heat soak at this temperature for approximately 2 hours to eliminate all traces of carbon. Nickel chromium (base metal alloys) were used for casting and the castings were done in induction casting machine. The preheated quartz crucible is held with casting tongs and placed in a bracket on the casting machine and then metal ingots were placed in the crucible. The casting machine is wound and given one or two extra wound to compensate for the much lighter density of the base metal alloy.The casting machine is then closed followed by standard casting technique. After casting is performed, it is removed and Sandblasted to remove residual investment material.

5. Finishing of the casting:

The inside of the restoration is examined for particles of stone or smudges of the relief agent and that are found are removed with the no.330 bur. Now the casting is finished. The occlusal grooves are smoothed with a no.1 carbide bur. The rough finishing on all accessible areas is then performed with the no.8 aluminium oxide coral wheel. Occlusal morphologic features (triangular ridges, cusp ridges and cusp inclines) are finished with a mounted coral aluminium oxide tapered stone and inverted cone stone. The casting is smoothed with rubber wheels.

6. Polishing of the casting:

Blue wheel and tips are used to smooth areas that are still rough. Than the casting is smoothened with white rubber wheel. Now the polishing compound (Tripoli, rouge) is used on a felt disk for axial surfaces and on felt cones for occlusal anatomy. The casting is thoroughly cleaned, and the high shine is applied with a fine-grit polishing compound on felt disks and cones.

RESULTS

The present in vitro study was done to compare the marginal accuracy of castings produced with ringless and metal ring investment systems.

Table – I; demonstrates the mean vertical marginal discrepancy and standard deviation of all the groups and all the surfaces of individual groups. The least vertical marginal discrepancy is showed by **Group A** (110.75µ) and the maximum vertical marginal discrepancy is showed by **Group D** (165.75µ). The second least vertical marginal discrepancy is showed by **Group C** (135.75µ) followed by **Group B** (144.50µ) and **Group E** (163.00µ).

Table –II; demonstrates the mean vertical marginal discrepancy values of all the groups along with the standard deviation and standard error.

The mean marginal discrepancy, for each group used were calculated and data were tabulated and analysed by means of " one way ANOVA" test, followed by the "Post Hoc LSD" and "Post HocTukey B" multiple comparison test. Statistical significance level was set $p< 0.05$. (**Table III** to **Table V**)

Table – III; Shows one way ANOVA test among different groups. It shows significant value in vertical marginal discrepancy among all the groups ($p<0.05$).

Table – IV; Shows "Post Hoc LSD" multiple comparison test for marginal discrepancy between different groups.

The mean vertical marginal discrepancy values in **Group A** showed statistically significant result ($P<0.05$) when compared to **Group D** and **Group E.**

The mean vertical marginal discrepancy values in **Group B** showed statistically non- significant result when compared to all other groups.

The mean vertical marginal discrepancy values in **Group C** showed statistically non-significant result when compared to all other groups.

Table 1: Mean vertical marginal discrepancy and standard deviation of all groups and all the surfaces.

GROUPS	Sample numbers (all values are in microns)												
	SURFACE	1	2	3	4	5	6	7	8	9	10	MEAN	SD	AV. OF ALL SURFACES
A	MESIAL	130	100	120	60	120	100	100	70	90	100	99	21.833	110.75
	BUCCAL	80	90	100	80	110	170	140	130	100	120	110	24.495	
	DISTAL	140	150	140	100	90	150	90	110	120	140	122	22.998	
	PALATAL	120	70	60	90	150	140	90	160	70	150	112	40.497	
B	MESIAL	150	110	100	210	130	80	170	130	130	220	143	45.473	144.50
	BUCCAL	150	190	170	220	160	90	140	190	170	190	167	35.606	
	DISTAL	170	160	90	250	170	100	120	190	130	140	152	47.093	
	PALATAL	90	120	90	90	210	120	130	100	100	110	116	35.963	
C	MESIAL	220	100	230	90	110	100	310	100	60	150	147	80.007	135.75
	BUCCAL	180	140	140	60	230	160	250	140	100	190	159	56.853	
	DISTAL	150	120	190	90	200	180	190	80	80	220	150	53.541	
	PALATAL	70	80	90	110	90	70	80	70	100	110	87	15.670	
D	MESIAL	100	100	230	80	270	170	190	190	260	100	169	70.938	165.75
	BUCCAL	110	130	210	110	290	110	180	220	270	190	182	66.633	
	DISTAL	110	200	250	100	270	100	220	240	290	110	189	76.369	
	PALATAL	100	140	100	120	190	150	120	130	90	90	123	31.287	
E	MESIAL	120	250	60	110	100	110	230	280	240	130	163	78.038	163.00
	BUCCAL	130	260	90	180	230	120	90	260	190	190	174	64.498	
	DISTAL	170	150	260	160	170	160	100	200	300	100	177	63.078	
	PALATAL	80	210	140	180	120	40	120	170	210	110	138	55.337	

Table 2: Shows mean marginal discrepancy values along with their standard deviation and standard error for all the groups.

Groups	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Group A	10	110.75	16.0316	5.0696
Group B	10	144.50	27.355	8.6506
Group C	10	135.75	40.569	12.829
Group D	10	165.75	52.692	16.662
Group E	10	163.00	46.305	14.642
TOTAL	50	143.95	42.432	6.0008

Table 3: Shows one way ANOVA test among different groups.

		Df	Sum of Squares	Mean Square	F	Sig.
Marginal Accuracy	Between Groups	4	20079.250	5019.812	3.315	.018
	Within Groups	45	68146.875	1514.375		
	Total	49	88226.125			

Table 4: Showing "Post hoc LSD Test" multiple comparisons for marginal discrepancy between different groups.

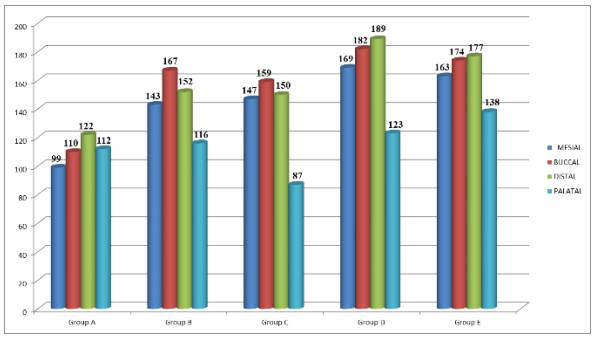
AVERAGE LSD	**Group(I)**	**Group(J)**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**
	Group A	B	33.7500	17.40	.059
		C	-49.490*	17.40	.158
		D	55.000	17.40	.003
		E	-52.250	17.40	.004
	Group B	A	33.750	17.40	.059
		C	-8.7500	17.40	.618
		D	21.250	17.40	.228
		E	18.500	17.40	.293
	Group C	A	25.00	17.40	.158
		B	8.75	17.40	.618
		D	30.00	17.40	.092
		E	2.7250	17.40	.124
	Group D	A	55.00	17.40	.003
		B	21.25	17.40	.228
		C	30.00	17.40	.092
		E	2.75	17.40	.875
	Group D	A	52.250	17.40	.004
		B	18.500	17.40	.293
		C	27.250	17.40	.124
		E	2.750	17.40	.875

Table 5: Showing "Post hoc Tukey B" Test for comparing mean vertical marginal discrepancies values between the different groups.

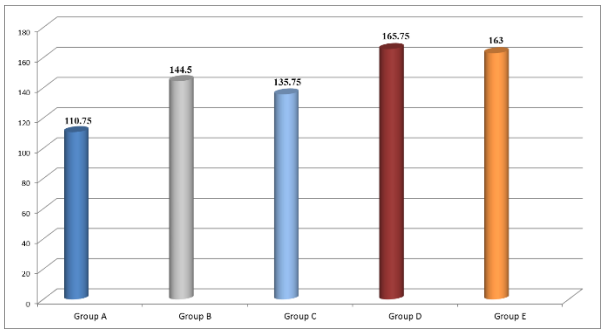
	Group	N	Subset for alpha = 0.05	
			1	2
Tukey B	A	10	110.75	
	C	10	135.75	135.7500
	B	10	144.50	144.50
	E	10		163.000
	D	10		165.7500

The mean vertical marginal discrepancy values in **Group D** showed statistically significant result (P<0.05) when compared to **Group A.**

The mean vertical marginal discrepancy values in **Group E** showed statistically significant result (P<0.05) when compared to **Group A.**



Graph 1: Comparison of mean vertical marginal discrepancy of all the surfaces of all the groups.



Graph 2: Comparison of Mean vertical marginal discrepancy (microns) of various groups.

Table – V; Shows "Post Hoc Tukey B" Comparison test for comparing mean marginal discrepancy between different groups.

It showed decreased mean vertical marginal discrepancy values of **Group A** when compared to **Group C, Group B, Group E** and **Group D.**

It showed decreased mean marginal discrepancy of **Group C** when compared to **Group B, Group D** and **Group E.**

It showed decreased mean vertical marginal discrepancy values of **Group B** when compared to **Group E** and **Group D.**

It showed decreased mean vertical marginal discrepancy values of **Group E** when compared to **Group D.**

It showed increased marginal discrepancy values of **Group D** when compared to **Group E**, **Group B, Group C** and **Group A.**

Result of the present study revealed that the castings produced by ringless technique fits better than the castings produced by using the conventional metal ring technique. The casting produced using deguvest impact investment material with ringless technique showed the mean vertical marginal discrepancy of (110.75µ) which is least among all the groups.

Ringless technique with biosint extra investment material showed the mean vertical marginal discrepancy of (135µ) which is second least among all the groups.

The casting produced by metal ring technique with deguvest impact investment material showed more accurate casting and less vertical marginal discrepancy than the castings produced by metal ring technique with biosint extra investment material.

In the group in which the deguvest impact investment material was used there were two ways of investing the wax pattern that is with the dry cellulose ring liner and the wet cellulose ring liner and the values were (144µ) and (165µ) respectively. This shows that the conventional metal ring casting method with dry ring liner has less vertical marginal discrepancy then the casting done with wet ring liner.

Among the deguvest impact investment material and biosint extra investment material using the conventional metal ring casting technique the biosint extra showed (163µ) vertical marginal discrepancy which is more than the deguvest impact investment material using dry ring liner (144µ).

This shows that the deguvest impact investment material gives more accurate results then the biosint extra investment material and ringless method of casting gives more accurate results than the conventional metal ring casting technique.

DISSCUSSION

The accuracy of fit of a cast restoration is essential for its longevity because it allows for less plaque accumulation at the marginal area, provides better mechanical properties (stability, resistance), less cement space (less possibilities for leakage), and improves the aesthetic result.The accuracy of fit is affected by the quality of the preparation, the impression, the working Cast, the quality of the wax

that is used for the lost wax technique, and by the accuracy of the castings[3].

The purpose of this study was to ascertain whether the ringless technique can be routinely used for the fabrication of cast restoration. To fulfill the requirements for an ideal restoration a casting must be made to fit the prepared tooth intimately. Success or failure of fixed restorations depends upon a number of factors; one of which is the marginal integrity. Marginal fit of the restoration helps in maintaining the harmonious relationship between tooth, periodontium and restoration itself[1, 3, 4].

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. To compensate for this limitation, an asbestos liner was used. The asbestos liner that was in use for many years was abandoned because asbestos is associated with carcinogenesis[3, 5]. So Cellulose liners are used as a substitute.

Though the casting with metal ring is a reliable and time-tested technique which produces clinically acceptable marginal accuracy, there is a positive restriction on the expansion of mould due to the ring. Investigation needed to find 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.

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[5].

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 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[6].

In this study the marginal accuracy of all metal complete coverage crowns fabricated with ringless and metal ring investment technique using biosint extra (the plaster free phosphate bonded investment material for partial dental work) and deguvest impact (phosphate bonded crown and bridge investment material) and using wet and dry cellulose ring liner technique is evaluated on all the four surfaces of the metal coping under travelling microscope.

The present study compared the vertical marginal accuracy of copings between the ringless and metal ring investment techniques with two different investment i.e. deguvest impact and biosint extra and the results were better for ringless technique **(GROUP A and GROUP C) (TABLE- I, TABLE II and GRAPH II)**.

According to statistical analysis **Group A** showed statistically significant result ($P<0.05$) when compared to Group **D** and **Group E** and statistically non-significant when compared to Group **B** and Group **C**. It showed decreased mean vertical marginal discrepancy when compared to **Group C, Group B, Group E** and **Group D (TABLE IV, TABLE V).**

From the above mentioned observation it is clear that the casting produced form ringless technique provide better marginal accuracy.

This can be explained on the ground that in this technique, complete expansion of the mould during setting and thermal expansion of the mould takes place uniformly in all the directions without any restriction. The setting expansion was also not restricted as the plastic ring was opened up immediately on initial set of investment.

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[7, 8].

Ringless technique with deguvest impact investment material (**GROUP – A)** showed the mean

vertical marginal discrepancy of (110.75µ) which is least among all the groups. Ringless technique with biosint extra investment material **(GROUP – C)** showed the mean vertical marginal discrepancy of (135µ) depicted in **(TABLE I, GRAPH II)** which is second least among all the groups.

Result of the present study revealed that the castings produced by ringless technique **(GROUP A and GROUP C)**fits better than the castings produced by using the conventional metal ring technique **(GROUP B, GROUP D** and **GROUP E)**.

Although the metal ring technique is clinically acceptable and allows for the fabrication of accurate casts, 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[9]. The compensation for the shrinkage inherent in the dental casting procedure may be obtained by either one or both of the following two methods;

- Setting or hygroscopic expansion of the investment
- Thermal expansion of the investment

Both of these techniques are correctly in use and are commonly termed the hygroscopic expansion (low-heat) method and the thermal expansion (high-heat) method, respectively. As their names along might indicate, the high heat method requires thermal expansion of the investment to occur between room temperature and a high temperature (650degree to 700 degree centigrade for gypsum bonded investment and up to 1050 degree Celsius for phosphate bonded investments).

A total expansion of 2 percent or more is required for alloys used to produce metal ceramic prosthesis, since these gold based, palladium based, and base metal alloys have higher melting and solidification temperature. These entire requirements for compensating the shrinkage were better obtained using the ringless technique of investing and casting[10, 11].

In metal ring technique we use liner in two ways to compare the marginal discrepancy value. Among them it is found that the use of dry ring liner gives much better accuracy of the coping then using wet ring liner within same metal ring **(TABLE- I, TABLE II** and **GRAPH II).**

Statistical analysis showed that the values obtained from **Group B** (144 µ) compared to **Group D** (165µ) showed less marginal discrepancy. So the present study support the opinion that the dry cellulose ring liner technique provides better compressive strength and the copings also show more accurate results. **(TABLE- I, TABLE II and GRAPH II)**. **Group B** showed statistically non– significant (P>0.05) result when compared to all other groups and it showed decreased mean vertical marginal discrepancy when compared to Group E and Group D (TABLE IV, TABLE V).

The reason for this is that in dry liner group none of the spaces between the castings and the die could be attributed to inadequate setting expansion whereas in wet liner group spaces between the castings and the die could be attributed to inadequate setting expansion. Among the deguvest impact investment material and biosint extra investment material using the conventional metal ring casting technique the biosint extra (GROUP – E) showed (163µ) vertical marginal discrepancy which is more than the deguvest impact investment material using dry ring liner (GROUP – B) showing (144µ) as showed in (TABLE II,GRAPH II).

CONCLUSION

1. The casting produced by ringless technique fits better than the castings produced by using the conventional metal ring technique.
2. Ringless technique with deguvest impact investment material showed less vertical marginal discrepancy than ringless technique with biosint extra investment material.
3. The casting produced by metal ring technique with deguvest impact investment material showed more accurate casting and less vertical marginal discrepancy than the castings produced by metal ring technique with biosint extra investment material.
4. The conventional metal ring casting method with dry ring liner has less vertical marginal discrepancy then the casting done with wet ring liner.

5. The deguvest impact investment material gives more accurate results then the biosint extra investment material.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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