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Comparative evaluation of marginal fit of metal copings fabricated by direct metal laser sintering system and conventional lost wax technique an in vitro study

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I. Introduction

Fixed partial denture has always been considered as the golden standard for replacement of missing teeth as it will improve patient's comfort, masticatory ability, and patient's self-image[1].

Marginal adaptation is an important criteria for the long term clinical success of the restorations. Increased marginal discrepancy favors the rate of cement dissolution and increases the potential for micro leakage and plaque retention, which in turn raises the risk of recurrent caries, inflammation of vital pulp and onset of periodontal diseases[2].

Although traditionally metal copings have been fabricated by the lost wax technique (LW) and casting method, possible problems have been suggested related to this complex procedure for crown fabrication. For example, making impressions in the oral cavity may incur discomfort for patients and inaccurate marginal fit may result from contraction of impression material, distortion of wax patterns, or irregularities in the cast metal. In efforts to overcome the limitations of the LW method, computer-aided design/computer-aided manufacturing (CAD/CAM) systems have been introduced with various ways to produce a dental prosthesis.

In recent years there has been an enormous growth in the interest in technologies for additively manufacturing parts in metal. This technology was born out so-called rapid prototyping (RP) technologies in the 1990s and were driven by the vision of a future where additive manufacturing could be as widespread and accepted as subtractive manufacturing methods are today[3]. Traditional material subtractive manufacturing technologies such as, milling, tapping, turning, etc. create 3D physical models by removing material using cutting tools.

Although the advance in Computerized Numerical Control (CNC) and High Speed (HS) milling technologies which reduce process time and increases the productivity, one major disadvantage is the dependence on the geometric complexity. Some features as small holes inside a block are hard to manufacture due to the process constraints and when the sample size is small, the time for process planning can constitute a significant portion of the time needed to manufacture the part[4].Differently of traditional subtractive machining processes, Rapid Prototyping (RP) is a group of techniques used to quickly fabricate prototypes or assembly models using 3-D computer aided design (CAD) data using layer-by-layer fabrication process.

There are several RP machines that utilize different building methods and materials, such as 3-D printing, fused deposition modelling, laminated object manufacturing, selective laser sintering (SLS), selective laser melting (SLM) and 3-D laser cladding[5]. Every RP technique has its advantages and disadvantages respectively, among which SLS is an optimal method to directly manufacture metal parts because of its wider material range and better flexibility[6].

Direct metal laser-sintering (DMLS) system is an additive metal fabrication technology, based on information received from three dimensional CAD, in which metal powder is shot selectively using a data file and fused with a laser to laminate approximately a 20–60 μm-thick layer with each shooting to complete a metal structure.

Advantages of the DMLS system include easy fabrication of complicated shapes, operation of an automatic system, and short working time due to elimination of the procedures of fabricating a wax pattern, investing, burnout, and casting. While the traditional casting method using the LW method might waste metal in spruing and other procedures, the DMLS system could reduce metal waste by selectively shooting the required amount. One disadvantage of the DMLS system is the expensive price of the equipment. While the marginal fit obtained with DMLS technique, to other techniques determine the long term clinical success of restoration. [(7-12)]

The purpose of this study is to evaluate the marginal fit of metal copings fabricated by direct metal laser sintering system and conventional lost wax technique (figure 6).

Aims and Objective

1. To evaluate the marginal fit of metal copings fabricated by direct metal laser sintering system and conventional lost wax technique.
2. To evaluate the feasibility to use the copings fabricated following direct metal laser sintering (DMLS) technique routinely for clinical purpose.

II. Material and Method

The study was conducted in Department of Prosthodontics, Crown & Bridge and Implantology, Rishiraj College of Dental Sciences and Research Centre in assistance with Department of Oral Pathology, Rishiraj College of Dental Sciences and Research Centre, Gandhinagar Bhopal, M.P. and Direct Metal Laser Sintering was done in Illusion Dental Lab Pvt. Ltd. Andheri west, Mumbai.

FABRICATION OF MASTER METAL DIE

A precisely machined stainless steel master die was designed (figure 1) to simulate a complete molar crown preparation. The die measured 6 mm from the occlusal surface to finish line with a 6° taper towards the occlusal surface from the finish line. The metal die was mounted on a cylindrical base of 20 mm length and a diameter of 10 mm. A shallow axial groove was given for orientation of casting during seating. Four reference marks were scribed one each on the buccal, lingual, mesial and distal areas on the root stump near the cervical margin around the circumference of the die. These marks were used later as reference marks for the measurements (figure 2).

A counter die with dimensions 1.5 mm larger than the master die was made in order to make wax patterns of uniform dimensions.[13]

METHOD EMPLOYED IN THE STUDY FOR CONVENTIONAL LOST WAX TECHNIQUE:

For easier understanding the methodology has been discussed under the following headings --

• Fabrication of wax patterns
• Investing
• Burnout
• Casting
• Recovery of the casting

FABRICATION OF WAX PATTERNS

The Wax patterns were fabricated after applying a thin layer of die lubricant. The counter die was closed until the demarcated mark over the die to obtain a wax pattern of uniform thickness. The margins were readapted and refined using wax carving instruments (figure 3). Total 20 was pattern was fabricated. Final pattern was checked for its marginal integrity with the finish line of the master die.[13]

INVESTING

The wax patterns were sprued at 45°angle to the occlusal surface[14, 15]. The wax patterns were positioned within 4 to 6 mm of the top of the investment (figure 4), and placed as close as possible to the center of the ring.[14,15,16,17]

After spruing, the wax pattern was carefully removed from the dies so as to minimize distortion of the wax pattern. They were then attached to the crucible former and coated with a surface tension reducing agent. Patterns were invested in group of 7 copings at a time.

A single layer of ceramic liner was adapted to the 2 X casting ring and moistened by dipping in a bowl of water, and the excess water was shaken away.[2,4] They were invested with Bellasun (BEGO, Germany) phosphate-bonded investment (60gm of powder to 16 ml of 100% mixing liquid). [16]

The investment powder and liquid was hand spatulated for 15 to 20 seconds to incorporate the powder.[14, 15, 18] Then the investment was mechanically Vacuum mixed for 60 seconds.[14, 18]After placing the lined casting ring over the pattern, with the aid of vibration, the investment was poured down the side of the ring. The ring was filled slowly. The investment was allowed to set for 2 to 3 hours before proceeding with burnout.[17]

BURNOUT

The casting ring was placed in a burnout furnace at room temperature and the temperature was raised to 250°C and maintained for 60 minutes. Thereafter the temperature was raised to 950ºC and held for 30 minutes.[14, 17]

CASTING

After completion of the burnout the casting procedure was carried out in an Induction -casting machine using Nickel-Chromium alloy.

RECOVERY OF THE CASTING

The castings were recovered by divesting the investment. Burswere used to remove the investment from the inner surface of the casting such as a thin layer of investment left behind. Sandblastingwas done to remove the residual investment and oxide layer.

FABRICATION OF COPINGS WITH DIRECT METAL LASER SINTERING SYSTEM

Master die was scanned by laser scanner (Geomagic capture Phenix, 3D System France)(figure 5). An experienced dental technician designed 1.5 mm-thick coping including 30 µm of cement film thickness margin using CAD software (figure 6 & 7) (Pronest2015, software, Phenix, 3D System France), following the manufacturer’s instructions, and completed standard template library (STL) files that were used to fabricate metal frameworks using the DMLS system (PRO X 100 DP, Phenix, 3D System France). The DMLS technology fuses metal powder into a solid part by melting it locally using the focused laser beam and builds up additively layer by layer, typically using layers 20 µm thick.[15] A cobalt–chromium (Co–Cr) alloy powder with major components of cobalt–chromium–molybdenum tungsten (Co–Cr–Mo–W) according to the EN ISO 2768 (fine) standard, was used.

MEASUREMENT OF THE MARGINAL FIT OF THE CASTINGS

The completed castings were seated on the metal die under finger pressure. The marginal discrepancy between the metal die and the castings were measured on an Optical stereo microscope Measurements were made at predetermined points that were marked on the metal die, at the buccal, mesial, lingual, and distal areas (figure 8 & 9). All measurements were executed by a single operator and the readings were tabulated and used for the statistical analysis.

STATISTICAL ANALYSIS:

The data obtained was subjected to statistical analysis with the consult of a statistician. The data so obtained was compiled systematically. A master table was prepared and the total data was subdivided and distributed meaningfully and presented as individual tables along with graphs.

Statistical procedures were carried out in 2 steps:

1. Data compilation and presentation
2. Statistical analysis

Statistical analysis was done using Statistical Package of Social Science (SPSS Version 20; Chicago Inc., USA). Data comparison was done by applying specific statistical tests to find out the statistical significance of the comparisons. Quantitative variables were compared using mean values. Significance level was fixed at P ≤ 0.05.

Statistical Tests Employed For The Obtained Data In Our Study Were:

1. Student’s t-test:

The Student’s t-test was used to analyze the variation in mean between two groups of a variable with a normal distribution.

Independent sample

$\bar{X}_1$ and $\bar{X}_2$ = Mean of group one and two respectively.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{SEd}$$

$$\text{SEd} = \left(\frac{SS1 + SS2}{df1 + df2}\right) \Big/ (n1 + n2)$$

Where,

$SS_1 + SS_2$ = sum of squared deviation of group one and two respectively
df_1 and df_2 = degree of freedom of group one and two respectively
n_1 and n_2 = number of samples in group one and two separately.

2. **P Value denotes level of significance:**
   P > 0.05 Not significant
   P <0.05 Significant (significant at 95% confidence level)
   P <0.01 Highly Significant (significant at 99% confidence level)
   P <0.001 Very Highly significant (significant at 99.9% confidence

III. Result

The present study was conducted:
To evaluate the marginal fit of metal copings fabricated by direct metal laser sintering system and conventional lost wax technique.
To evaluate the feasibility to use the copings fabricated following direct metal laser sintering (DMLS) technique routinely for clinical purpose.
Total 40 copings were fabricated, 20 with conventional lost wax (LW) techniques and 20 with direct metal laser sintering (DMLS).
Named as:
Group 1: copings prepared with conventional lost wax technique.
Group 2: coping prepared with direct metal laser sintering system (figure 10).
All the copings were checked for their marginal discrepancy using an Optical Stereomicroscope and the readings were tabulated.
The data obtained was subjected to statistical analysis with the consult of a statistician. The data so obtained was compiled systematically. A master table was prepared and the total data was subdivided and distributed meaningfully and presented as individual tables along with graphs.

Statistical procedures were carried out in 2 steps:

3. Data compilation and presentation
4. Statistical analysis

Statistical analysis was done using Statistical Package of Social Science (SPSS Version 20; Chicago Inc., USA).

Statistical Tests Employed For The Obtained Data In Our Study Were:

3. Student's t-test:

The Student's t-test was used to analyze the variation in mean between two groups of a variable with a normal distribution.
Independent sample

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$$\text{SEd} = \left(\frac{SS1 + SS2}{df1 + df2}\right) \Big/ (n1 + n2)$$

Where,

$SS_1 + SS_2$ = sum of squared deviation of group one and two respectively
df_1 and df_2 = degree of freedom of group one and two respectively
n_1 and n_2 = number of samples in group one and two separately.

Table 1: shows the marginal gap of copings fabricated by conventional lost wax technique at Buccal, Lingual, Mesial and Distal areas. The marginal gap of conventional lost wax copings were found to be 39.01-67.32 µ at Buccal area, 38.54-57.63 µ at lingual area, 39.45-59.02 µ at Mesial area and 35.88-64.11 µ at Distal area.

Table 2: Shows the marginal gap of copings fabricated by Direct Metal Laser Sintering technique at Buccal, Lingual, Mesial and Distal areas. The marginal gap of Direct Metal Laser Sintering copings were found

to be 15.04-27.04 µ at Buccal area, 15.04-26.85 µ at lingual area, 16.03-28.93 µ at Mesial area and 17.46-25.55 µ at Distal area.

Table 3 Graph 1: Shows the Mean Marginal gap between Conventional Lost Wax (LW) & Direct Metal Laser Sintering (DMLS) coping at Buccal Area. The mean marginal gap of conventional lost wax copings were found to be 49.523 ± 7.917 and the mean marginal gap of direct metal laser sintering copings were found to be 20.486 ± 3.271, with the difference being statistically highly significant (P = 0.001).

Table 4 Graph 2: Shows the mean marginal gap between conventional lost wax technique & direct metal laser sintering copings at lingual area. The mean marginal gap of conventional lost wax copings were found to be 47.188 ± 5.655 and the mean marginal gap of direct metal laser sintering copings were found to be 20.690 ± 3.273, with the difference being statistically highly significant (P= 0.001).

Table 5 Graph 3: Shows the mean marginal gap between conventional lost wax technique & direct metal laser sintering copings at mesial area. The mean marginal gap of conventional lost wax copings were found to be 48.272 ± 5.795 and the mean marginal gap of direct metal laser sintering copings were found to be 20.787 ± 2.846, with the difference being statistically highly significant (P= 0.001).

Table 6 Graph 4: Shows the mean marginal gap between conventional lost wax technique & direct metal laser sintering copings at distal area. The mean marginal gap of conventional lost wax copings were found to be 50.554 ± 8.162 and the mean marginal gap of direct metal laser sintering copings were found to be 20.640 ± 3.175, with the difference being statistically highly significant (P= 0.001).

Table 7 Graph 5: Shows the mean marginal gap between conventional lost wax technique & direct metal laser sintering copings at all four areas. The mean marginal gap of conventional lost wax copings were found to be 48.884 ± 5.194 and the mean marginal gap of direct metal laser sintering copings were found to be 20.651 ± 2.491, with the difference being statistically highly significant (P= 0.001).

Table 1: The marginal gap of copings fabricated with conventional lost wax technique at Buccal, lingual, mesial and distal areas.

S.No.	LW	BUCCAL (µ)	LINGUAL (µ)	MESIAL (µ)	DISTAL (µ)	Mean
1	1	43.49	39.09	47.32	57.44	46.835
2	1	40.12	43.33	41.03	40.01	41.1225
3	1	39.01	45.71	42.11	48.31	43.785
4	1	51.33	38.54	44.76	53.44	47.0175
5	1	59.63	48.02	44.31	57.01	52.2425
6	1	67.32	59.43	59.02	63.07	62.21
7	1	58.03	51.33	49.09	54.32	53.1925
8	1	49.02	44.54	42.05	43.22	44.7075
9	1	50.36	47.82	43.91	64.11	51.55
10	1	49.53	42.31	54.43	59.53	51.45
11	1	61.83	57.63	52.34	58.33	57.5325
12	1	47.01	43.67	39.45	35.88	41.5025
13	1	40.87	45.18	54.39	50.01	47.6125
14	1	50.55	49.32	47.09	56.72	50.92
15	1	47.51	43.32	47.34	50.97	47.285
16	1	56.74	51.23	44.76	42.34	48.7675
17	1	39.96	41.24	48.32	45.95	43.8675
18	1	47.32	51.22	58.43	45.76	50.6825
19	1	49.91	53.38	55.74	41.34	50.0925
20	1	40.93	47.45	49.56	43.32	45.315

Table 2: The marginal gap of copings fabricated with Direct Metal Laser Sintering (DMLS) technique and Buccal, lingual, mesial and distal areas.

S.No.	DMLS	BUCCAL (µ)	LINGUAL (µ)	MESIAL (µ)	DISTAL (µ)	Mean

1	2	23.01	19.32	20.45	25.55	22.0825
2	2	19.71	20.89	18.43	22.04	20.2675
3	2	17.56	20.12	16.03	19.32	18.2575
4	2	23.04	21.11	20.47	19.98	21.15
5	2	17.85	19.01	21.06	20.73	19.6625
6	2	27.04	24.31	22.45	21.97	23.9425
7	2	17.99	15.04	19.72	18.45	17.8
8	2	24.02	19.9	21.43	22.87	22.055
9	2	25.04	26.85	21.04	19.04	22.9925
10	2	18.45	23.41	26.07	19.51	21.86
11	2	15.04	18.72	21.04	17.46	18.065
12	2	20.43	19.2	21.31	19.38	20.08
13	2	18.74	23.17	21.04	19.87	20.705
14	2	17.34	15.56	16.92	19.45	17.3175
15	2	18.32	23.37	20.51	19.29	20.3725
16	2	26.34	24.74	28.93	31.32	27.8325
17	2	19.42	15.67	18.94	17.45	17.87
18	2	21.47	24.73	19.87	20.23	21.575
19	2	18.46	19.23	18.28	21.07	19.26
20	2	20.45	19.46	21.75	17.83	19.8725

Table 3: Comparison of Mean Marginal gap between Conventional Lost Wax (LW) & Direct Metal Laser Sintering (DMLS) Coping at Buccal Area.

COPING	**Number**	**Mean Marginal Gap (µ)**	
		MEAN	**SD**
Conventional Lost Wax(LW)	**20**	49.523	7.917
Direct Metal Laser Sintering(DMLS)	**20**	20.486	3.271
Unpaired Student 't' Test		**15.159**	
P Value		**0.001(HS)**	

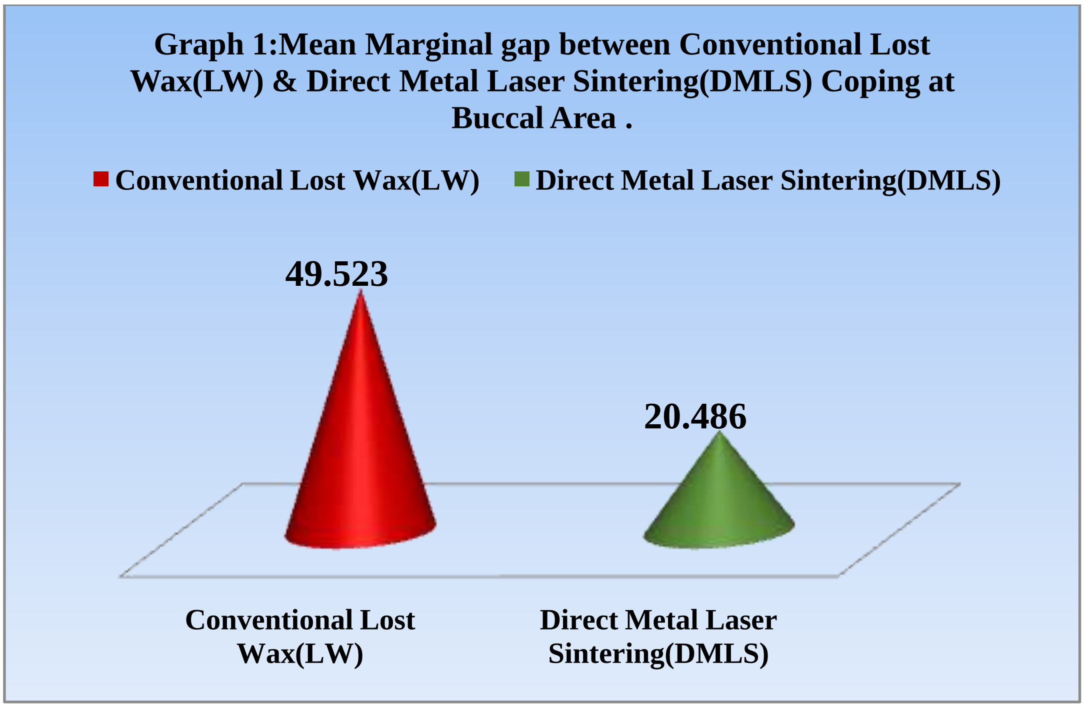


Table 4: Comparison of Mean Marginal gap between Conventional Lost Wax (LW) & Direct Metal Laser Sintering (DMLS) Coping at Lingual Area.

COPING	Number	Mean Marginal Gap (µ)	
		MEAN	SD
Conventional Lost Wax(LW)	**20**	47.188	5.655
Direct Metal Laser Sintering(DMLS)	**20**	20.690	3.273
Unpaired Student 't' Test		**18.135**	
P Value		**0.001(HS)**	

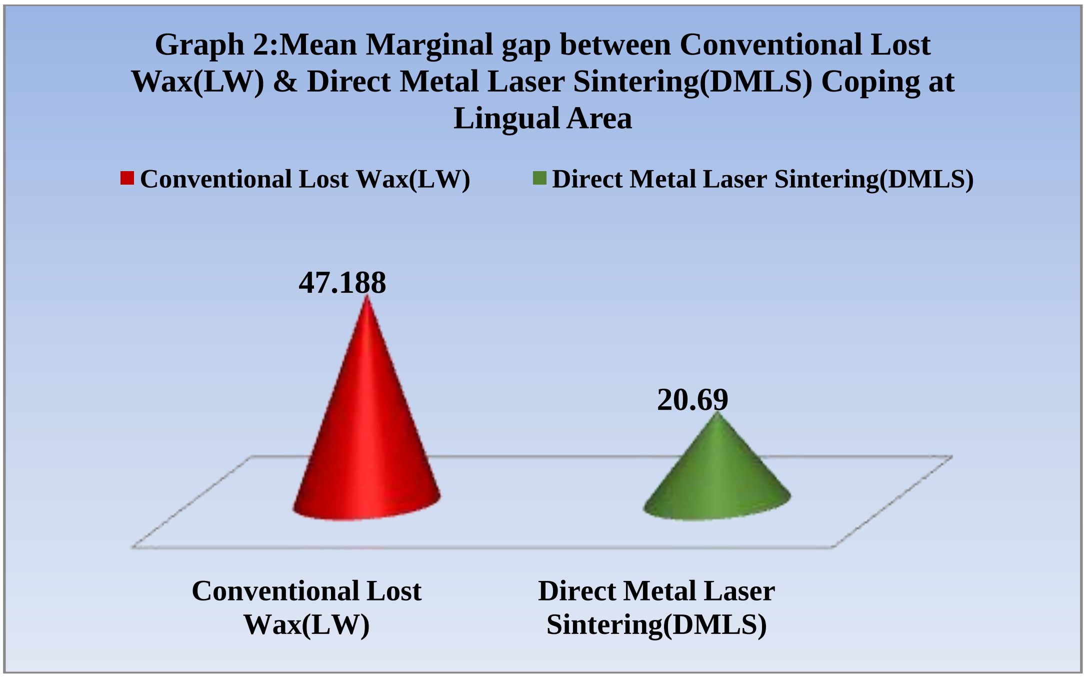


Table 5: Comparison of Mean Marginal gap between Conventional Lost Wax (LW) & Direct Metal Laser Sintering (DMLS) Coping at Mesial Area.

COPING	Number	Mean Marginal Gap (µ)	
		MEAN	SD
Conventional Lost Wax(LW)	**20**	48.272	5.795
Direct Metal Laser Sintering(DMLS)	**20**	20.787	2.846
Unpaired Student 't' Test		**19.036**	
P Value		**0.001(HS)**	

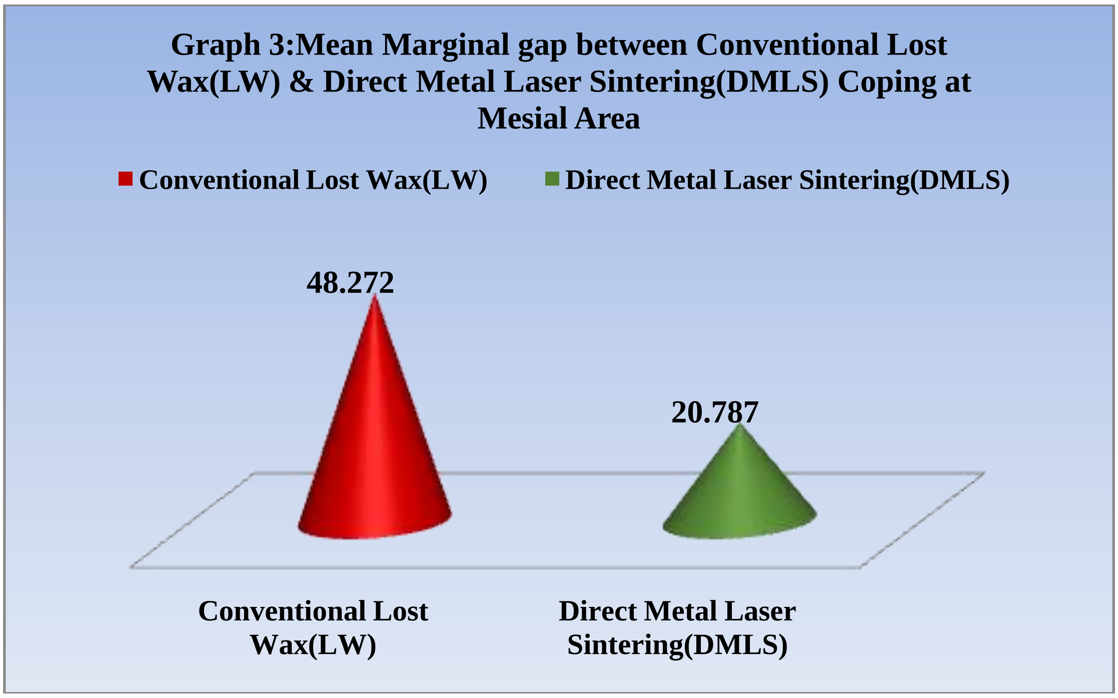


Table 6: Comparison of Mean Marginal gap between Conventional Lost Wax (LW) & Direct Metal Laser Sintering (DMLS) Coping at Distal Area.

COPING	Number	Mean Marginal Gap	
		MEAN	SD
Conventional Lost Wax(LW)	20	50.554	8.162
Direct Metal Laser Sintering(DMLS)	20	20.640	3.175
Unpaired Student 't' Test		15.275	
P Value		0.001(HS)	

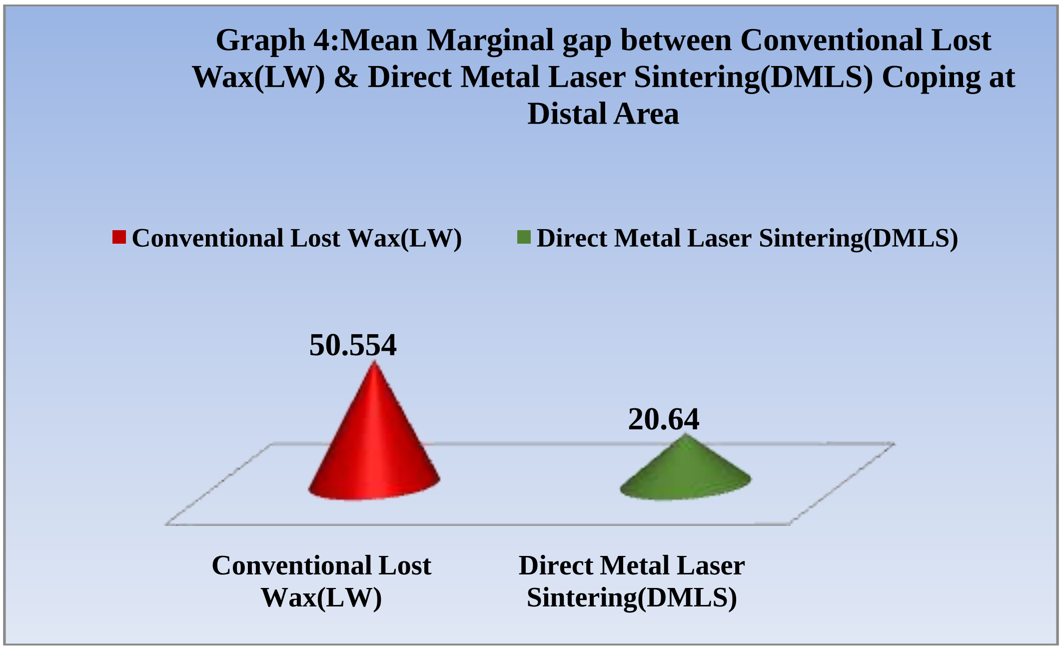
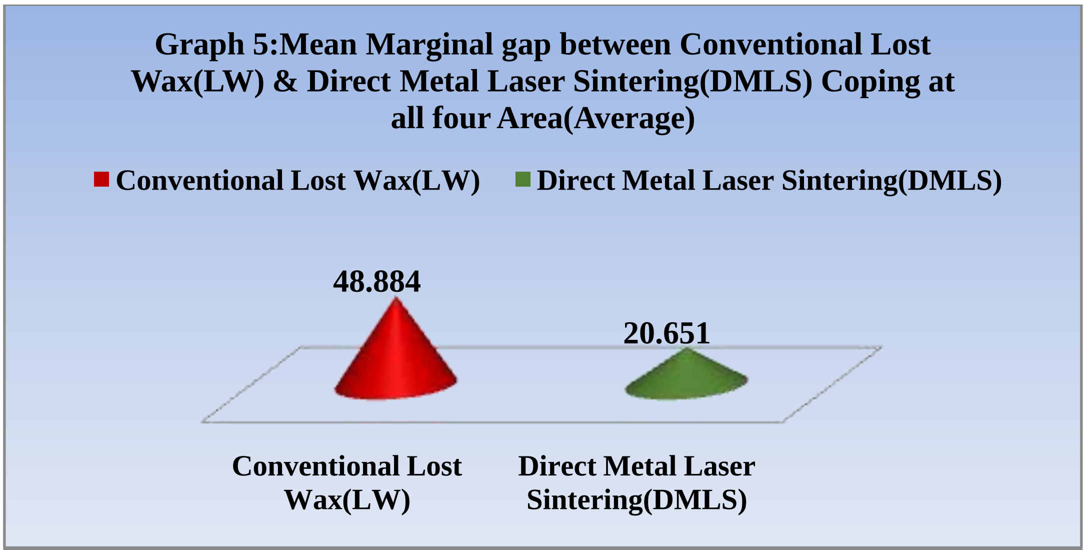
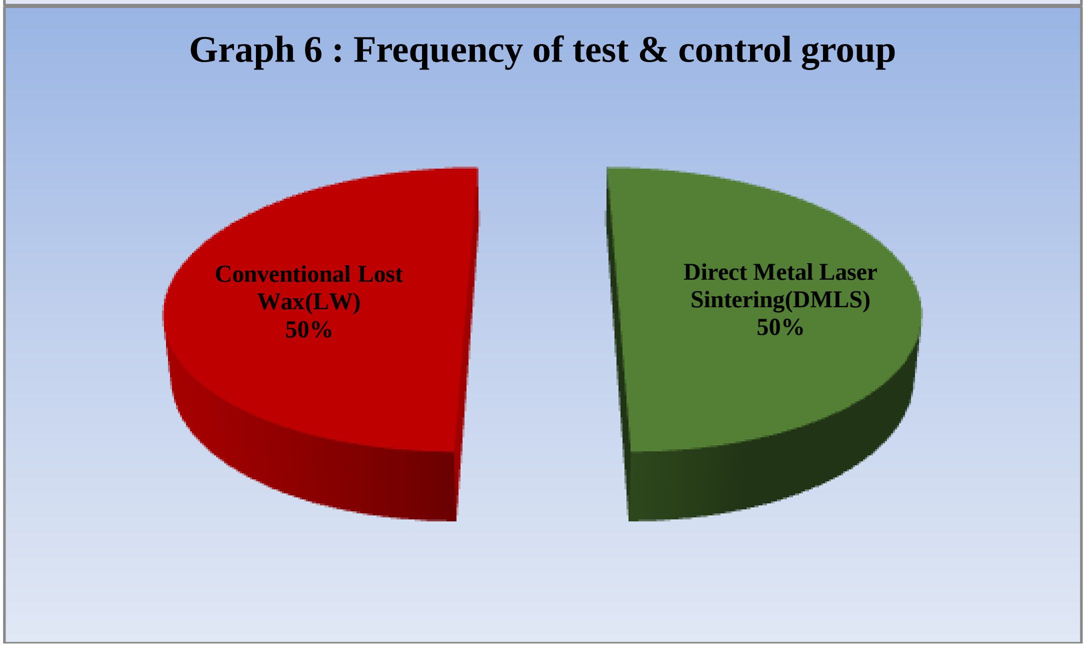


Table 7: Comparison of Mean Marginal gap between Conventional Lost Wax (LW) & Direct Metal Laser Sintering (DMLS) Coping at all four area (average) .

COPING	Number	Mean Marginal Gap	
		MEAN	SD
Conventional Lost Wax(LW)	**20**	48.884	5.194
Direct Metal Laser Sintering(DMLS)	**20**	20.651	2.491
Unpaired Student 't' Test		**21.916**	
P Value		**0.001(HS)**	





IV. Discussion

Fixed Prosthodontics has become a major part of current restorative dentistry because people are living longer, seeking more dental care, and are more educated about their dental health.[19]

Fixed prosthodontic treatment can offer exceptional satisfaction for both patient and the dentist. Fixed prosthodontics can transform an unhealthy, unattractive dentition with poor function into a comfortable, healthy occlusion capable of giving years of further service while greatly enhancing esthetics[19]. To achieve success, requires meticulous attention to every detail from initial patient interview through the active treatment phases to a planned schedule of follow-up care.

Fixed partial denture is any dental prosthesis that is luted, screwed or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implant abutments that furnish the primary support for the dental prosthesis (GPT 8).

Various alloys and techniques have been introduced for the casting of the fixed partial dentures.[20]

Alloys used in dentistry can be broadly classified into 3 categories, high noble, noble and predominantly base metal alloys (ADA 1985). Ever escalating cost of gold has made a paradigm shift to the use of base metal alloys ever since their introduction to the profession over 50 years. Although used for some time as a substitute for partial denture frame works, they now have 58 more extensive purposes, typical example includes castings and wrought alloys for the fabrication of crown, bridges, dental implants and orthodontic appliance.[21]

The advantage of substituting base metal alloys for those containing gold are several. Many of the mechanical properties of the base metal alloys are superior to that of the gold alloys. By comparison, gold and other noble metal alloys are substantially more expensive.[21]

Of all the base metal alloy systems, the most successful are Ni - Cr alloys, Ni and Cr forming the major component and the balance of the composition includes Mo, Si, Fe and Ce. The properties of this alloy are: density that is one half that of gold alloy, modulus of elasticity that is 2 to 2 1/2 times more than that of the gold alloy, sag resistance that is 9 times greater, yield strength that is approximately 20,000 Psi. greater, elongation values between 3 and 22 per cent, and cost that is one fifth that of the gold alloy.

Base metal alloy substructures may be finished thinner than noble alloys, provide greater resistance to deformation, and therefore provide increased strength to the restorations.[22]

The majority of the fixed partial dentures are fabricated using “conventional” investing and casting techniques, which usually require at least 1 hour setting time for the investment, followed by a two-stage (temperature is increased from room temperature to 250ºC and held for 60 min and then the temperature is increased to 950ºC gradually and held for 30 min) wax elimination procedure before casting is done. The whole process requires approximately 2 to 4 hours for completion and is time-consuming.[20, 13, 14]

In efforts to overcome the limitations of the LW method, computer-aided design/computer-aided manufacturing (CAD/CAM) systems have been introduced with various ways to produce a dental prosthesis. The newly developed direct metal laser-sintering (DMLS) system is an additive metal fabrication technology, based on information received from three dimensional CAD, in which metal powder is shot selectively using a data file and fused with a laser to laminate approximately a 20–60 µm-thick layer with each shooting to complete a metal structure. Advantages of the DMLS system include easy fabrication of complicated shapes, operation of an automatic system, and short working time due to elimination of the procedures of fabricating a wax pattern, investing, burning, and casting works. While the traditional casting method using the LW method might waste metal in spruing and other procedures, the DMLS system could reduce metal waste by selectively shooting the required amount. One disadvantage of the DMLS system is the expensive price of the equipment. While an essential condition for a successful dental prosthesis is good marginal fit.[7-11]

This study was conducted to compare the marginal fit of metal copings fabricated by direct metal laser sintering system and conventional lost wax technique. That uses phosphate bonded investment material and a Nickel- Chromium alloy for the conventional casting and cobalt–chromium (Co–Cr) alloy powder with major components of cobalt–chromium–molybdenum-tungsten (Co–Cr–Mo–W) for Direct Metal Laser Sintering (DMLS).

To avoid all possible variables such as polymerization shrinkage of impression materials, expansion of die stone, and die spacer thickness, the wax patterns of the lost wax technique were fabricated directly on the stainless steel master die[23, 17], and the same die was used for scanning for DMLS.

Wax distortion is probably the most serious problem that can occur during fabrication and removal of the pattern from the die. This distortion results from thermal changes and the relaxation of stresses that are caused by contraction on cooling, occluded air in the wax, molding, carving, removal, and the time and temperature of storage.[14]

The stress relief is the time dependent reduction of residual stresses, manifested as a delayed elastic recovery (elastic memory) that produced corresponding distortion[14, 17, 24]

The wax may expand as much as 0.7% with an increase in temperature of 20°C, or it may contract as much as 0.35% when it is cooled from 37° to 25°C. The average linear coefficient of thermal expansion over such a temperature range is 350x10-6/ 0C.[14]

The linear dimension of inlay wax changes 0.04% for each degree change in temperature, and inlay wax has a thermal expansion of 0.6% for 10° rise of temperature.[18]

The expansion and shrinkage of casting wax is very sensitive to temperature. Inlay wax thermally expands and contracts more per degree change in temperature than any other dental material.[23]

When selecting waxes for optimal casting accuracy, the use of waxes with different properties for the margin and occlusal portions are necessary.[14, 25]

The wax with low softening temperature results in less casting shrinkage whereas the wax with higher softening temperature results in greater casting shrinkage.[14]

In the present study the wax with lower softening temperature was used for the complete pattern.

In spite of utmost care, the marginal discrepancies in wax patterns were ground to happen. In the present study, the wax patterns were fabricated directly on the metal master dies.

When the molten wax flows on a cool metal die the wax immediately adjacent to the die solidifies rapidly because the heat from the molten wax is rapidly dissipated. The wax adjacent to the air stays molten for a long period of time. As it solidifies and contracts it pulls the previously congealed wax away from the metal.[18]

To minimize the distortion of the wax pattern it is advised to use low storage temperature and it should be invested immediately after fabrication.[14, 25]

For DMLS copings master die was scanned by laser scanner (Geomagic capture Phenix, 3D System France). An experienced dental technician designed 1.5 mm-thick coping including 30 µm of cement film thickness margin using CAD software (Pronest2015, software, Phenix, 3D System France), following the manufacturer's instructions, and completed standard template library (STL) files that were used to fabricate metal frameworks using the DMLS system (PRO X 100 DP, Phenix, 3D System France).

The DMLS technology fuses metal powder into a solid part by melting it locally using the focused laser beam and builds up additively layer by layer, typically using layers 20 µm thick.[15] A cobalt–chromium (Co–Cr) alloy powder with major components of cobalt–chromium–molybdenum tungsten (Co–Cr–Mo–W) according to the EN ISO 2768 (fine) standard, was used.

The marginal discrepancy of copings fabricated by conventional lost wax technique and direct metal laser sintering system was measured using an Optical stereomicroscope.

The mean vertical marginal discrepancies of Conventional lost wax technique copings and direct metal laser sintering system copings were compared using Student's unpaired t-test. Statistically significant differences were found between the mean vertical marginal discrepancies of Conventional lost wax technique and direct metal laser sintering technique $P<0.001$).

Raquel Castillo Oyagu et al (2012), they found the vertical discrepancy was affected by alloy/manufacturing technique and cement type ($P< 0.001$). Despite the luting agent, Laser Sintered structures showed the best marginal adaptation, followed by vacuum cast Pd–Au, and vacuum cast Co-Cr.

Raquel Castillo-Oyagu et al (2013), they concluded that the DMLS of Co–Cr may be a reliable alternative to the casting of base metal alloys to obtain well-fitted implant-supported crowns, although all the groups tested were within the clinically acceptable range of vertical discrepancy. No strong correlations were found between misfit and microleakage. Notwithstanding the framework alloy, definitive resin-modified glass-ionomer (FP) and temporary acrylic/urethane-based (DT) cements demonstrated comparably better marginal fit and greater microleakage scores than did 10 methacryloxydecyldihydrogen phosphate-based (CEC) and self-adhesive (RXU) dual-cure resin agents[26].

Baek Kim et al (2013), concludedmarginal fit of FDPs in the group fabricated by the DMLS system were significantly inferior to those of the LW group ($p < 0.001$) and had slightly larger gaps than the acceptable range[27].

Sundar et al (2015) concluded that the copings fabricated using MLS technique had a better marginal fit and an observable decrease in microleakage when compared to the copings fabricated using the conventional lost wax (LW) technique, the mean marginal fit of copings before and after ceramic addition in MLS was statistically significant ($P < 0.05$) when compared with conventional technique[28].

Clinical tolerance limits for the fit and marginal adaptation of a cast restoration are actually not known. However, several investigations reported that marginal gaps in cast crowns of up to 74 μ, 104 μ, or 120 μ are considered to be clinically acceptable.[29]

In the present study mean vertical marginal gap was 48.884μ ± 5.194 and 20.651μ ± 2.491 for group 1 copings (Conventional lost wax LW) and group 2 copings (Direct Metal Laser Sintering DMLS) respectively, these values are well within the clinical tolerance limits.

V. Conclusion

Under the conditions of this study the following conclusions were drawn:

1. The marginal accuracy of the Metal copings fabricated by Direct Metal Laser Sintering technique was statistically highly significant to that of the Conventional Lost Wax casting technique.
2. Clinically acceptable complete castings can be obtained with the Direct Metal Laser Sintering system

VI. Summary

Lost wax technique was introduced by William H. Taggart in 1907,[29] since then the Conventional casting technique is followed to fabricate majority of the fixed partial prosthesis and it produces castings with clinically acceptable marginal accuracy.

Marginal adaptation is an important criteria for the long term clinical success of the restorations. Increased marginal discrepancy favors the rate of cement dissolution and increases the potential for micro leakage and plaque retention, which in turn raises the risk of recurrent caries, inflammation of vital pulp and onset of periodontal diseases.

To reduce the marginal gap and to improve fit a new technique called direct metal laser sintering (DMLS) was introduced.

The accuracy of fit of the cast restoration is essential for its longevity and clinical success. Nickel-Chromium base metal alloy is most commonly used for the castings, and Cobalt- Chromium used for DMLS because of their better mechanical properties.

Till date very few studies have been reported about the marginal accuracy of full coverage crowns fabricated by direct metal laser sintering technique.

The present study was conducted to compare the marginal accuracy of Metal copings fabricated by Conventional lost wax casting technique and Direct metal laser sintering technique.

The wax patterns were fabricated directly over a precisely machined stainless steel master die designed to simulate a complete molar crown preparation. A counter die with dimensions 1.5 mm larger than the master die was made in order to make wax patterns of uniform dimensions.[13]Twenty wax patterns were fabricated using conventional method, and the same metal die is scanned to prepare twenty coping with Direct metal laser sintering (DMLS).

Group1: Representing copings made following Conventional Casting technique.

Group 2: Representing copings made following direct metal laser sintering (DMLS) technique.

Phosphate-bonded investment material was used for conventional group, the investment was allowed to set for 2 to 3 hours before proceeding with burnout.[17]

The following schedules of Burnout were followed: The casting ring was placed in a burnout furnace at room temperature and the temperature was raised to 250°C and maintained for 60 minutes. Thereafter the temperature was raised to 9500 C and held for 30 minutes.[17]

After burnout the casting procedure was carried out, the castings were recovered. Only gross surface adjustments were done and the castings were seated on the master die using finger pressure and the marginal gap between the master die and copings were assessed.

For group 2 copings master die was scanned by laser scanner (Geomagic capture Phenix, 3D System France). An experienced dental technician designed 1.5 mm-thick coping including 30 μm of cement film thickness margin using CAD software (Pronest2015, software, Phenix, 3D System France), following the manufacturer's instructions, and completed standard template library (STL) files that were used to fabricate metal frameworks using the DMLS system (PRO X 100 DP, Phenix, 3D System France). The DMLS technology fuses metal powder into a solid part by melting it locally using the focused laser beam and builds up additively layer by layer, typically using layers 20 μm thick. A cobalt–chromium (Co–Cr) alloy powder with major components of cobalt–chromium–molybdenum tungsten (Co–Cr–Mo–W) according to the EN ISO 2768 (fine) standard, was used.

The copings were measured at the predetermined areas using an Optical stereomicroscope. The values obtained were tabulated and statistically analyzed using Student's unpaired t-test.

The mean marginal gap of conventional lost wax copings were found to be 48.884 ± 5.194 and the mean marginal gap of direct metal laser sintering copings were found to be 20.651 ± 2.491, with the difference being statistically highly significant (P= 0.001).

The vertical marginal discrepancy produced by the direct metal laser sintering (DMLS) technique were well within the maximum clinical tolerance limits (120 μ) and can be used routinely for clinical purpose.

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