THE FEASIBILITY OF INDIRECT CASTING OF MAXILLARY REMOVABLE PARTIAL DENTURE

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امكانية صب الشبكة المعدنية لأطقم الأسنان الجزئية العلوية بالطريقة غير المباشرة

على الرغم مما ذُكِرَ بأنه يمكن صب الشبكات المعدنية لأطقم الأسنان الجزئية العلوية بالطريقة المباشرة أو غير المباشرة، فإنه مايتم صبها إلا بالطريقة المباشرة.

هذا وقد أُجريت هذه الدراسة على ثلاثون عينة قياسية من الأطقم الجزئية العلوية التي تم صبها بمعدن الكروم كوبالت. تم صب نصفها بالطريقة المباشرة والنصف الآخر بالطريقة غير المباشرة باستخدام التصميم نفسه. وتم فحص العينات إشعاعيًا وكذا بالعين المجردة وبالاستعانة بعدسة مكبرة.

وقد تبين من الدراسة أنه بالامكان الحصول على الشبكات المعدنية لأطقم الأسنان الجزئية العلوية سليمة وخالية من عيوب الصب كالفقاعات الهوائية وغيرها عند صبها بأي من الطريقتين المباشرة وغير المباشرة على حدٍ سواء.

Although it is stated that maxillary removable partial dentures may be cast by both direct and indirect liquid metal feeding, they are generally cast by the direct spruing and metal feeding techniques. This study is undertaken to determine, both visually and radiographicaily, the soundness, i.e. absence of porosities, of indirect maxillary removable partial denture framework castings. It is concluded that sound maxillary removable partial denture components can be obtained with the indirect method.

Introduction

The desirable removable partial denture framework should show no sizeable defects within its structure to be able to fulfill its function. Yet many removable partial denture castings contain internal and external defects of varying size and shape, which can cause failure or plastic deformation of the prosthesis[1] and increased corrosion of the alloy.[2] The presence of porosities in a casting will predispose the prosthesis to failure in one of two ways.[3] A large discrete void will reduce the cross sectional thickness of metal to the point that simple tensile failure may occur such voids are readily visible during an examination of fracture sites. In addition, smaller intrametallic defects, frequently consisting of aggregation of microporosities, may cause failure by acting as initiation sites for fatigue cracks - such microporosity is not detectable at fracture surfaces since it is rendered inconspicuous by the invariably coarse and highly dendritic surface texture of castings.

According to Elarbi et al,[1] structural defects may not cause fracture of a removable partial denture framework, but they will increase the possibility of plastic deformation of certain components leading to casting misfit. Such deformation may be related to overall tissue adaptation, fit on the supporting teeth, or both.

Structural faults in dental castings can result from any combination of problems related to spruing,[4-10] investing,[8,9,11] wax elimination,[4,6,11-14] alloy melting,[4,6,7,11] casting,[5,11,15] and solidification of

Received 16/11/92; revised 31/01/93; accepted 03/03/93

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the casting.[4] According to Vaidyanathan et al,[16] some of the most important defects that can occur are: shrinkage porosity, porosity due to occluded gases, porosities and/or defects due to "back pressure" of gases in the mold, porosities due to inclusion of investment, incomplete filling of the margins due to surface tension defects, and suck back porosities. To avoid porosity and incomplete filling of the mold cavity,[17] the gases must be evacuated from both the molten metal and the mold cavity before the metal solidifies. One factor that helps gas elimination, while the mold cavity fills completely with minimum metal turbulence, is proper sprue design. Preston and Berger[18] have stated that "spruing is an art which is not well understood". The efficacy of a sprue system depends on how easily the metal can flow through it and fill the mold cavity. The sprue must supply molten metal continuously to force gases out of the mold cavity and compensate for the shrinkage of the alloy casting as it solidifies.

The configuration of the sprues, from their point of attachment at the crucible former until they reach the mold cavity, may be influential in reducing turbulence,[19] thus, sprue channels should make long radii, easy turns and also enter the mold cavity from a direction designed to avoid splashing at this point.

The method of attaching sprue formers differs slightly depending upon the location of the crucible former, which may be in the base of the cast, known as the indirect spruing technique [Fig. 1], or suspended above the pattern, known as the direct spruing technique [Fig. 2].[20] In casting crowns and inlays the direct technique is credited for quick feeding of the liquid metal. The indirect technique was found to decelerate the metal and prevent potential fracture of delicate components of the mold cavity.[21]

Traditionally mandibular removable partial dentures are sprued by the indirect spruing technique because it is easier to attach the sprue leads. In addition, this method of spruing takes advantage of the overjet principle. In the overjet principle, the initial thrust of molten metal is directed against the tip of the central sprue and the resulting turbulence and impurities are confined to this area rather than being distributed to the casting.

While it was stated[21] that maxillary removable partial dentures may also be sprued indirectly if the shape of the casting permits, they are generally sprued by the direct spruing technique. No previous comprehensive studies were made to compare the soundness of maxillary removable partial denture castings sprued by one approach *versus* the other.

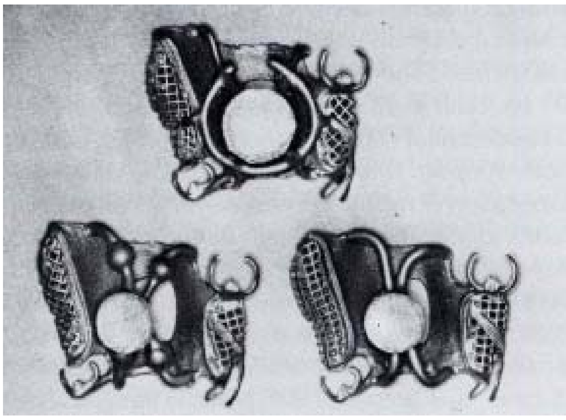

Fig. 1. Indirect spruing technique

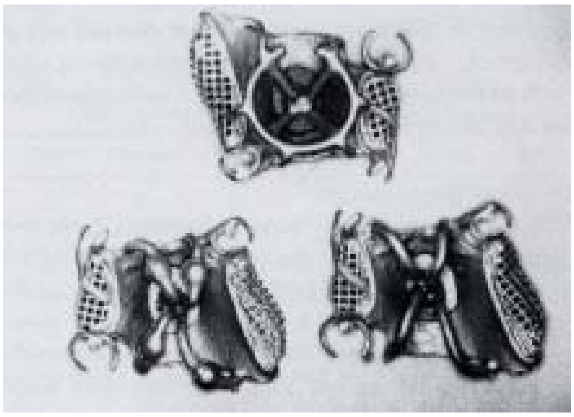

Fig. 2. Direct spruing technique

This study is undertaken primarily to determine both visually and radiographically the number of possible casting defects or the degree of porosity in maxillary removable partial denture framework castings sprued by the direct versus the indirect spruing technique.

Materials and Methods

A Class II modification I partially edentulous maxillary cast was chosen to serve as the test master cast. The cast was surveyed, and a removable partial denture design was selected. An anterior-posterior palatal strap major connector was utilized. The direct retainers selected were an RPI on tooth # 13 on the distal extension side and circumferential clasps on tooth # 16, # 24 on the tooth supported side. Wax blackout, relief, and duplication of the master cast were carried out with Perfex duplicating material* in the conventional manner to produce thirty refractory casts which were divided into two groups. A group of fifteen casts were used in the usual manner for direct spming technique. The other group, comprised of 15 casts, was prepared with holes in their bases for the indirect spruing technique. Identical wax patterns were made using preformed wax** for clasps, major connectors, and retentive meshworks. Each group was further divided into 3 sub-groups each consisting of 5 refractory casts. Each of the sub-groups was sprued with one of the spruing arrangements used by Talic.[22]

1) *Tree Sprue Design*

The crucible former was suspended over the center of the cast with the point *of cone about* 10 mm. above the highest point of the pattern. Four (4) sprue formers, each 3 mm. in diameter were curved in a posterior direction from the underside of the crucible former to the pattern and were attached at four different spots on the major *connector.*[20]

2) *The Circular Sprue Design*

The circular feeder was made from a 3 mm. diameter wax. The auxiliary sprue formers emanating from the circular feeder were 6 in number, each was 2 mm. in diameter and were attached directly to the major connector. The circular feeder was attached to the wax crucible former by 4 sprue formers, each 3 mm in diameter.

3) *The Ball Sprue Design*

The ball sprue design consisted of 3 mm diameter feeders as with the tree sprue design except that a 5 mm ball reservoir was attached to each feeder 5 mm away from the wax pattern.

In all phases of spruing, abrupt changes in direction, and T-shaped junctions were avoided to guard against turbulence which caused gas entrapment and leads to faulty casting. In addition, the molten metal might break these sharp angles of investment and carry them into the casting.[20]

In summary, ten refractory casts were thus sprued by each of the three spruing arrangement, five by direct spruing technique and five by indirect spruing technique. All wax patterns were invested using the same batch of Wirovest investment material.*

Refractory casts were left to bench set for 2 hours before burnout took place. The burnout was carried out according to the manufacturer's specifications. The test samples were cast using 25-35 grams of Wironit cobalt-chromium alloy.**The variation in weight of the casting metal was due to differences in the spruing arrangement. The appropriate weight for each spruing arrangement was determined experimentally in a pilot study. A centrifugal induction casting machine was used and the metal was cast at 1200°C. The centrifugal *force* used was 9 bars. After the castings were divested, they were blasted with 50 micron aluminum oxide,*** then conventionally finished and polished. Finally, castings were ultrasonicaliy cleaned. All castings were coded and a standardized assessment form was utilized to record casting regarding inaccuracies in six different areas. These areas were the major connector, the three direct retainers, and the two meshworks.

Each component of the metal framework examined was scored from 0-5 based on the number of defects visible after sandblasting and polishing of the frameworks. No defects was scored as 0, one defect in a given component was scored as 1, two defects in a given component or one defect in each of two components of the same type (2 clasps) or different types (retentive meshwork + major connector) was scored as 2 and so on.

* Perfex (Batch # 056022), Austenal Dental Products, Chicago, Illinois, USA

** Bego pre-formed wax, Bego-postfach 419220, D-2800, Bremen, 41 West Germany

* Bego Batch # 51051, Bego-postfach, D-2800 Bremen, 41 West Germany

** Bego Batch # 50030, Bego-postfach 419220, D-2800, 41 West Germany

***Korox 50 batch # 46062, Bego-postfach 419220, D-2800 Bremen, 41 West Germany

Radiographs were taken by utilizing an X-ray machine* at 15 mA and 90kV (P) using occlusal films. Each casting was given a code number, and similar lead numerals were included in the exposure so that cross identification could be made. During each radiographic exposure, the central beam was perpendicular to the specimen surface.

Each radiograph was placed in an envelope carrying a random number. The radiographs were then evaluated and ranked by the two clinicians independently in a semi-dark room with a variable high intensity illuminator** and a glass magnifier (X5).

While adaptability was not the goal of this research, all frameworks were tried on duplicates of the master cast and were visually determined to be acceptable.

Results

Typical maxillary RPD framework castings prepared by direct metal feeding using each of the three spruing methods is shown in Fig, 1. Those obtained by indirect metal feeding are shown in Fig. 2. Since 30 removable partial denture frameworks were cast and each of them was ranked in three components, and each ranking was done by two methods namely: visual and radiographic examinations, then the number of observations obtained was 180 (30 X 3 X 2). Each observation is expressed as a categorical value ranging from 0 to 5.

The mean visual clasp defect rankings by two independent investigators are reported in Table 1. It should be noted that only one clasp showed one defect. The mean visual major connector defect rankings are reported in Table 2. It should be noted that 24 defects were observed with as many as three defects in one major connector. The mean visual meshwork defect rankings are reported in Table 3; 12 casting defects were observed, and four defects occurred in the two meshwork areas of one removable partial denture. The mean radiographic defect ranking of clasps, major connector, and meshwork are reported in Tables 4-6, respectively.

* Heliodent 70 Model, Siemens Medical Engr., Inc., Beshin,

West Germany

" CCR Medical Corp, Baltimore, MD, USA

The radiographic clasp rankings are in agreement with the visual ones. The radiographic major connector rankings were also in general agreement with the visual ones except in the indirect tree design. In this event, radiographic major connector rankings showed higher defect incidence rate than visual ranking (Table 2 vs. 5).

The radiographic meshwork rankings were in lesser agreement with their visual rankings than clasps and major connector. However, radiographic meshwork rankings showed higher defect incidence rate than visual ranking in the direct circular spruing method.

To analyze the observations, many statistical techniques have been applied. Since we are not interested in the variation due to examiners, the

Table 1. Visual clasp ranking.

Direct Feeding			Indirect Feeding		
Tree	Circular	Ball	Tree	Circular	Ball
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	1	0	0

0 - No defect 1- One defect 2 - Two defects

Table 2. Visual major connector ranking.

Direct Feeding			Indirect Feeding		
Tree	Circular	Ball	Tree	Circular	Ball
3	0	1	0	5	4
I	1	I	0	0	0
0	0	0	0	1	i
1	1	1	0	1	0
1	0	0	0	0	1

0 - No defect 1-One defect 2 - Two defects
3-Three defects 4-Four defects 5 - Five defects

Table 3 Visual meshworkranking.

Direct Feeding			Indirect Feeding		
Tree	Circular	Ball	Tree	Circular	Ball
0	2	0	0	1	0
0	0	0	2	0	0
0	2	0	0	0	0
0	0	0	1	0	0
1	0	0	1	0	1

Table 4. Radiographic clasp ranking.

Direct Feeding			Indirect Feeding		
Tree	Circular	Ball	Tree	Circular	Ball
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	1

Table 5. Radiographic major connector ranking.

Direct Feeding			Indirect Feeding		
Tree	Circular	Ball	Tree	Circular	Ball
3	0	1	2	3	3
1	2	1	0	0	0
0	0	0	1	1	1
1	1	1	0	1	0
1	0	0	0	0	1

Table 6.Radiographic maskwork ranking.

Direct Feeding			Indirect Feeding		
Tree	Circular	Ball	Tree	Circular	Ball
0	5	0	0	1	0
0	0	0	2	0	0
0	2	0	0	0	0
0	0	0	1	0	0
1	0	0	1	0	0

Table 7. Sample correlations

Ave. No. of	Ave. No.of Defects Observations	Spruing	Feeding	Method of Observation
	1.0000"	.968	.0108	.232
Defects	(36)**	(36)	(36)	(36)
Observed	.0000***	.5744	.9503	.8932
	.0968	1.0000	.0000	.0000
Spruing	(36)	(36)	(36)	(36)
	.5744	.0000	1.0000	1.0000
	.0108	.0000	1.0000	.0000
Feeding	(36)	(36)	(36)	(36)
	.9503	1.0000	.0000	1.0000
Method of	.0232	.0000	.0000	1.0000
Observation	(36)	(36)	(36)	(36)
	.8932	1.0000	1.0000	.0000

* Coefficient ** Sample size *** Significance level

Table 8. Multiple regression analysis

Independent variable	Coefficient	Std.Error	t-value	Sig.Level
Constant	0.186667	0.499101	0.3740	0.7109
Spruing	0.122222	0.222097	0.5503	0.5859
Feeding	0.008333	0.136006	0.0613	0.9515
Method of Observation	0.008571	0.065023	0.1318	0.8960

R-SQ (Adj) = 0.0000 SE = 0.666290 MAE = 0.504572
Durb. Wat. = 1.868
Previosly : 0.0000 0.000000 0.000000 0.000
36 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

average values for the two examiners were used. As an initial analysis, the correlation matrix has been computed. The elements of the matrix will show the simple correlations between the variables. Multiple linear regression analysis has been conducted to observe the effect of metal feeding (direct and indirect), spruing (tree, circular, ball) and observation method (visual, radiographic) on the observation value. For further understanding of data, analysis of variance has been computed.

Table 7 shows the sample correlations between the variables; average number of defects observed, feeding, spruing and observation method. Second, third and fourth elements of the first row shows the correlation between independent variables; spruing, feeding, and method of observation vs. the dependent variable: average *no.* of defects observed. All the three correlations are not significantly different from zero correlation. This level of correlation shows that the independent variables do not have any statistically significant effect on the dependent variable.

Results of multiple regression analysis are shown in Table 8. The multiple regression plane gives the following result:

$Y = 0.187 + 0.122 X_1, + 0.008 X_2 + 0.009 X_3$

Where Y = Estimated value of average no. of defects observed

X, = Feeding

X_2 = Spruing

X_3 = Methods of observation

t-value and significance level showed that all the three independent variables did not give any significant effect on the average number of defects observed.

Analysis of variance computation was performed to determine the significance of the multiple linear regression model, Table 9. ***P*-value** showed that the null hypothesis (variable affects outcome) should be rejected. It simply means that all the three independent variables did not affect the dependent variable as a whole. All three analyses; correlation, regression and analysis of variance (ANOVA) indicated the same result; that is feeding, spruing and method of observation had no effect on the average number of defects observed.

Table 9. Analysis of variance for the full regression.

Source	Sum of Square	DF	Mean Square	F-Ratio	P-Value
Model	0.143825	3	0.0479418	0.107991	.9548
Error	14.2062	32	0.443943		

Total (Corr.) 14.3500 35
R-squared = 0.0100227 Stnd. error of est. = 0.66629
R-squared (Adj. for d.f.) = 0
Durbin-Watson statistic = 1.86784

Discussion

The visual clasp rankings of Table 1 shows that only one ciasp of possible ninety (30 removable partial dentures X 3 clasps) showed porosity. This result suggests that sound clasp castings could be achieved using any of the three spruing arrangements tested whether the spruing technique was direct or indirect. It seems that sound clasp casting are dependent on neither spruing arrangement[22] nor on liquid metal feeding direction.

The visual major connector rankings of Table 2 shows 24 defects. It showed that the largest number of defects appeared when the metal feeding was indirect and spruing arrangement was circular or ball. This observation may suggest that in the presence of a large liquid metal volume, a more sound major connector is likely to be obtained with direct metal feeding. Indirect metal feeding is likely to yield sound major connector when a simple tree sprue design is used.

The visual meshwork ranking of Table 3 shows that poorest meshworks were obtained with direct feeding and circular spruing. It appears that meshwork casting requires a more immediate liquid metal access through thicker sprues whether the metal feeding was direct or indirect.

Radiographic clasp and major connector rankings in Tables 4 and 5, while in general agreement with visual rankings, showed more defects than visual rankings in at least one condition for each of the two removable partial denture components. The number of radiographic defects may exceed those observed visually when some of these defects are completely enclosed within the casting.

When the removable partial denture component was rather thin in cross section, such as meshworks, radiographic rankings of Table 6 was somewhat less capable of detecting defects observed visually in Table 3. Since it was quite difficult to obtain radiographs of the complete two meshworks in the same plane, some of the defects observed visually were not detected radiographically.

Conclusion

It is concluded that sound maxillary removable partial denture components would be obtained with the various spruing arrangement in this study whether metal feeding was direct or indirect.

Acknowledgment

The author gratefully acknowledge the experimental assistance offered by Prof. H. Mohammed-Al Tahawi, Chairman of the Department of Prosthetic Dental Sciences. Acknowledgement is also due to Dr. Nazir Khan, Biostatistician at the Research Center of the College of Dentistry for his most valuable assistance in the statistical analysis.

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