Distortion of a MOD Pattern Caused by the Setting and Hygroscopic Expansion of the Investment in the Casting Ring

II. Influence of W/P Ratio, Pattern Position in the Ring, and the Condition of the Asbestos Lining

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MOD patterns are distorted by expansion of the investment during setting in the casting ring. Using a simple idealized epoxy resin MOD pattern and two-dimensional photoelasticity, this investigation reports the distortion under several conditions, including W/P ratios, cases with and without asbestos lining, number of asbestos layers, condition of the asbestos lining (dry, wet, and applied silicone oil and vaseline), and the position of the MOD pattern in the ring.

Key Words: Distortion, MOD, Photoelasticity

INTRODUCTION

In Part I of this report,¹⁾ distortions of a MOD pattern caused by the expansion of an investment during setting in a casting ring were observed with time and analyzed dynamically by two-dimensional photoelasticity.

The asbestos lining affects the degree of distortion of a MOD pattern because the expansion of an investment during setting in the casting ring is affected considerably by both a cushioning by the asbestos lining and the amounts of water taking part in the hygroscopic expansion.²⁻⁴⁾ Further, the water/powder ratio (W/P) and the pattern position in the casting ring are also related to the degree of distortion.⁵⁻⁷⁾ Since the distortion which takes place during the setting and expansion of the investment cannot be entirely avoided,¹⁾ consideration of the degree of distortion occurring after investing a wax pattern in a ring makes it possible to evaluate the accuracy of casting. Dental precision casting methods use the setting and hygroscopic expansion to compensate for casting shrinkage.

In the present study, the authors used the method reported in Part I to investigate the distortion of the MOD pattern under the following conditions: different W/P ratios, with and without asbestos lining, different thicknesses of the asbestos layer, condition of the asbestos lining, and different positionings of the MOD pattern in the ring.

EXPERIMENTAL METHODS

The simple idealized MOD pattern, the experimental materials and procedures are as

Figure 1 Positions of MOD pattern in the casting ring

reported in Part I.¹⁾ The effects of the W/P ratio on the distortion of the MOD pattern was studied for three W/P ratios—0.41, 0.36, and 0.31—by removing the split casting ring at the setting time. In order to investigate the cushioning effect of the asbestos lining, experiments were performed with no asbestos lining to completely restrict expansion of the investment, and further by lining with one to five layers of asbestos dampened with 1.5 ml water per layer (wet asbestos). The effects of the hygroscopic expansion caused by the water included in the asbestos lining were studied by lining three layers of asbestos under the following four conditions: dry asbestos, wet asbestos, asbestos sprayed with silicone oil[#] (silicone asbestos), and vaseline-treated asbestos (vaseline asbestos). The silicone and vaseline asbestos were used to prevent the transport of water between the investment and the asbestos lining. The effects of the MOD pattern position in the ring (lined with three layers of wet asbestos in all cases) on the distortion were investigated for three positions as shown in Figure 1, with (a), the occlusal portion being near the asbestos lining; (b), near the center of the ring; and (c), near the cervical margins being near the asbestos.

The standard MOD pattern position was at the center of the ring as shown in Figure 1(b), and the standard W/P ratio of the investment was 0.36.

RESULTS

Figure 2 shows dark field isochromatic patterns obtained with no asbestos lining, showing the changes with time after the start of mixing. The MOD pattern is subjected to compressive loads developed during the setting of the investment because the expansion in the radial direction is restricted completely by the ring. The numbers represent the orders of the isochromatic fringes. Zero order fringes appear at 18 min (2 min after setting), showing that a compressive load has begun to work on the MOD pattern. At the occlusal portion, the zero order fringe disappears at 26 min, and the first order is observed at 35 min. The first fringe moves from the lower to the upper part of the occlusal portion as shown in the 35 min and 80 min isochromatic patterns. Changes in fringe orders has ceased at 80 min. Fringe orders of the occlusal and mesio-distal portions at 80 min are one and zero, respectively, showing that the compressive loads on the occlusal portion are larger than those on the mesio-distal portions.

Figure 3 shows dark field isochromatic patterns at 80 min after the start of mixing, obtained by varying the number of wet asbestos layers from one to five. Only half photo-

[#] Release, Shin-etsu Chemical Co., Tokyo, Japan

Figure 2 Dark field isochromatic patterns obtained by restricting setting expansion of the investment in the ring without asbestos lining, showing the changes with time after the start of mixing. The numbers on the isochromatic lines are the fringe orders

graphs are shown as the isochromatic lines appear symmetrically as shown in Part I.¹⁾ With the increase in distortion isochromatic lines accumulate at the inner corners of the MOD pattern; thus, the fringe orders at the inner corners are used to determine the degree of distortion. A plot of the measured fringe values at the inner corner against the number of asbestos layers is shown in Figure 4, revealing that distortion increases up to three layers of asbestos where it reaches a plateau.

Table 1 summarizes the fringe values at the inner corner of the MOD pattern as a measure of the magnitude of its deformation, obtained from isochromatic pattern after 80 min under several conditions: Numbers 1–3 show the effect of the different W/P ratios, revealing higher fringe orders with decreased W/P ratios. Since the amounts of setting expansion of the investment used in this study are 0.28% (W/P 0.41), 0.36% (W/P 0.36), and 0.43% (W/P 0.31), deformation of the MOD pattern increases with increasing setting expansion.

Numbers 4–8 show the effect of the number of wet asbestos layers (Figure 4). Numbers 9–12 were all obtained with three asbestos layers for the four different asbestos conditions, showing that the deformation increases in the order of dry, wet, vaseline, and silicone asbestos. As the measurement error of the fringe order was estimated to be ± 0.5 order, the differences in the degree of deformation between the vaseline and silicone asbestos can

Figure 3 Dark field isochromatic patterns at 80 min after the start of mixing, obtained by varying the number (one to five) of layers of wet asbestos

Figure 4 A plot of fringe values at the inner corners of the MOD pattern observed in Figure 3 against the number of wet asbestos layers

be disregarded.

Numbers 13–15 show the effect of the MOD pattern position in the ring. The deformation is similar both with the occlusal portion close to the asbestos lining (Figure 1(a)) and the MOD pattern in the center (Figure 1(b)), and it is larger with the cervical margin close to the asbestos lining (Figure 1(c)).

Table 1 Fringe values (after 80 min) at the inner corners of the MOD pattern as a measure of the magnitude of deformation

Condition No.	Pattern Position (shown in Fig. 1)	W/P	Asbestos Conditions	Layers of Asbestos Lining	Fringe Orders at the Inner Corners
1	(b)	0.41	Outer Casting Ring Removed		3.2
2		0.36			4.3
3		0.31			5.3
4	(b)	0.36	Wet	1	3.0
5				2	4.5
6				3	4.4
7				4	5.5
8				5	5.5
9	(b)	0.36	Dry	3	6.4
10			Wet		5.4
11			Silicone		4.2
12			Vaseline		4.3
13	(a)	0.36	Wet	3	5.3
14	(b)				5.4
15	(c)				6.6

Figure 5 Distribution of fringe values (after 80 min) on the inner surface of the MOD pattern. Thick solid lines are obtained from condition No. 2 shown in Table 1; broken lines, from No. 6; and thin solid lines, from No. 15.

Figure 5 shows the distribution of fringe values at the inner surface of the MOD pattern at 80 min, indicating the intensity in the direction perpendicular to the surface. The thick solid lines are from No. 2 in Table 1; the broken lines, from No. 6; and the thin solid lines, from No. 15. In the three different conditions the only differences are in the magnitude of the values. This result indicates that the behavior of the distortion is practically independent of these three conditions.

DISCUSSION

The isochromatic patterns (Figure 2) obtained with no asbestos lining are dissimilar to those (Figure 3) obtained with asbestos lining. The isochromatic fringes represent locations where the difference in the principal stresses is constant. When a uniform stress, σ , works on a photoelastic epoxy pattern, the relation between stress and fringe order, N , is represented by $N=Ct\sigma$, where C is the photoelastic sensitivity and t is the thickness of the epoxy pattern. Dark and light isochromatic patterns alternate uniformly on the pattern with increasing loads, starting with a dark isochromatic pattern (in a dark field) in the initial state with $\sigma=0$.⁸⁾

Figure 2, where the first order fringes move from the lower to the upper surface of the occlusal portion, indicates that the compressive stress is not uniform, but its gradient is small. Since the intensity of a pressure (per unit area) exerted by restricting the setting expansion of the investment completely is independent of the thickness of the mold,⁹⁾ the reasons why the compressive stress occurring on the occlusal portion is higher than that on the mesio-distal portions is not clear.

The MOD patterns where asbestos was lined in the ring and the split ring removed not only spread open in the mesiodistal direction but also had the parts subject to large displacements restricted by the outer mold wall.¹⁾ A space along the outer periphery of the MOD pattern, depending on the amount of expansion of the outer mold, affects the degree of restriction of its displacement and exerts an influence on the degree of the distortion. Expansion in the radial direction of the ring is made possible by the asbestos lining cushion. With fewer than three layers of asbestos as shown in Figure 4, a lack of cushioning affects the expansion; and the investment represses the radial expansion, resulting in a smaller distortion. However, the degrees of distortion with more than three layers of asbestos are identical because when there is extra cushioning capacity, the expansion of the investment between the mesial and distal portions (inner part of the MOD pattern) are the same under the conditions. The distortion is large with a large expansion from the effect of the W/P ratio (No. 1, 2, and 3 in Table 1). From these results the distortion of the MOD pattern becomes large only when both parts of the investment (outside and inside the MOD pattern) expand considerably. However, the behavior of the distortion does not change with the asbestos lining or removal of the casting ring.

The effects of the hygroscopic setting expansion caused by water contained in the asbestos lining can be explained as follows: In Table 1, the differences between the cases which allowed (No. 9 and 10) and prevented (No. 11 and 12) the movement of water from the asbestos to the investment show the effect of the hygroscopic setting expansion. This is not the effect of cushioning caused by different conditions in the asbestos because No. 11 and 12 show the same fringe orders as No. 2. This suggests that lining with more than three layers of asbestos can entirely eliminate the restriction of the casting ring in the expansion of the investment, as is also indicated from the results in Figure 4.

The dry asbestos lining (No. 9) displays higher fringe orders than the wet asbestos lining (No. 10) as a result of higher hygroscopic setting expansion—dry asbestos absorbs water from the investment mixture before setting, resulting in a lowering of the W/P ratio of the investment mixture. During setting the investment reabsorbs water from the asbestos, increasing the hygroscopic setting expansion. It has been reported that the amounts of

water taking part in the hygroscopic setting expansion are higher with dry asbestos lining than with wet asbestos lining¹⁰⁾ and the lower W/P ratios here cause a bigger hygroscopic setting expansion.

The differences in the fringe orders by changing the MOD pattern position (No. 13, 14, and 15 in Table 1) can also be explained by differences in the hygroscopic setting expansion. It has been reported that water from the asbestos layers does not penetrate to the center of the investment in the casting ring,¹⁰⁾ and so the water contained in the asbestos takes very little part in the hygroscopic setting expansion between the mesial and distal portions in Figure 1(a) and (b). However, the water influences the expansion of the investment in (c) because the cervical margins are close to the asbestos.

CONCLUSION

The influence of the W/P ratio, pattern position in the casting ring, and the asbestos lining (including no asbestos lining, number of layers, and its conditions) on the distortion of a MOD pattern during setting caused by expansion of the investment in the casting ring were investigated by two-dimensional photoelasticity using an epoxy resin MOD pattern.

With no asbestos lining a compressive stress worked on the MOD pattern with a gradually increasing setting expansion of the investment. The stress is not uniform over the whole pattern but is larger in the occlusal portion than in the mesiodistal.

The degree of deformation increases under conditions in which both expansion of the molds inside and outside of the MOD pattern becomes large, with smaller W/P ratio, and with an increase in the asbestos layers up to three layers. Lining with dry asbestos, the deformation is greater than with wet asbestos. When the cervical margins of the MOD pattern is close to the asbestos lining, the deformation also increases by increased hygroscopic setting expansion of the molds inside of the pattern.

The deformation changes in degree under several conditions; however, the behavior of the distortion does not change except for the case with no asbestos lining.

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REFERENCES

- 1) Ohno, H., Miyakawa, O. and Shiokawa, N.: Distortion of a MOD pattern caused by the setting and hygroscopic expansion of the investment in the casting ring (I), *Dent. Mat. J.*, 1: 33–46, 1982.
- 2) Fusayama, T., Kobayashi, Y., Takahama, Y., Hashimoto, Y., Inaba, T., Kurosu, I., Sakurai, S. and Suzuki, H.: Expansion of investment in the casting ring, *J.D.M.A.*, 3: 128–137, 1959, (in Japanese)
- 3) Palmer, D.W., Roydhouse, R.H. and Skinner, E.W.: Asbestos liner and casting accuracy, *D. Progress* 1: 156–163, 1961.
- 4) Yoshida, T., Yoshii, H., Suzuki, E., Ookawa, H., Itoh, Y. and Kiyota, K.: The setting expansion and the thermal expansion of investment of outside cervical region with crown type pattern in the casting ring, *Shigaku*, 66: 1051–1071, 1979, (in Japanese)
- 5) Mumford, G. and Phillips, R.: Dimensional change in wax patterns during setting of gypsum investments, *J.D. Res.*, 37: 351–358, 1958.

- 6) Mahler, D.B. and Ady, A.B.: The influence of various factors on the effective setting expansion of casting investments, *J. Pros. Den.*, **13**: 365–373, 1963.
- 7) Wakumoto, S. and Hanari, M.: Distortions of wax patterns invested by four different investing techniques depending in varying location and direction in casting ring, *J.D.M.A.*, **12**: 60–66, 1965, (in Japanese)
- 8) Frocht, M.M.: Photoelasticity (vol. I), *John Wiley and Sons, Inc.*, 1966, pp. 136–139.
- 9) Ohno, H., Miyakawa, O., Shiokawa, N., Nakano, S. and Kondo, S.: Expansion pressure during setting of an investment and the cushioning effect of asbestos lining, The 18th meeting of *J.D.A.M.*, **63**: 1970, (in Japanese)
- 10) Ohno, H., Miyakawa, O., Kondo, S., Nakano, S. and Shiokawa, N.: Setting expansion of investment in the casting ring (II), *J.D.A.M.*, **12**: 225–233, 1971, (in Japanese)

もっとも劣っていた。MFR では一定の回転数以上になると辺縁部の破折は起らなくなったが、従来型コンポジットレジンでは破折が持続した。コンポジットレジン

の marginal fracture toughness は、フィラーの粒径や配合率に影響をうけることがわかった。アマルガムはさらに著しい辺縁部の破折を示した。

鑄造リング内の埋没材の硬化膨張、水和膨張による MOD パターンの変形 (第1報) 二次元光弾性実験による直接的観察と力学的解析

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エポキシレジンで作製した MOD パターンを鑄造リング内に埋没し、二次元光弾性実験の等色線の観察をもとに、埋没材の硬化膨張、水和膨張によって生じたパターンの変形について力学的解析を行った。

パターンの変形速度は、埋没材の膨張速度に一致する。支台歯部位の埋没材の膨張によって、パターンは近遠心方向に開脚の変形を受ける。その結果、咬合部位に曲げモーメントと軸引張応力が作用する。また、変位の

大きい部分（歯肉側のマージン、咬合部位と脚部の接合部分）は、外周の埋没材壁に接するようになり、それぞれの変位が拘束される。MOD インレーの支台歯への適合を考える上で重要である歯肉側マージンの開脚による変位を分解すると、咬合部位の曲げと引張要素、それに脚部のたわみ要素の3つになる。全変位量に対するそれぞれの割合は、88%、2%、10%である。

鑄造リング内の埋没材の硬化膨張、水和膨張による MOD パターンの変形 (第2報) 変形におよぼす W/P, リング内でのパターンの位置, アスベストの条件による影響

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エポキシレジンで作製した MOD パターンを鑄造リングに埋没し、二次元光弾性実験によって、埋没材の硬化過程で生じたパターンの変形を観察した。変形形態や変形量におよぼす諸条件（W/P, アスベストの有無, アスベストの枚数および処理法, リング内でのパターンの位置）の影響について検討した。

アスベスト無の場合、膨張の発現に伴って徐々にパターンに圧縮応力が作用することが観察された。パターン外周と支台歯部の埋没材の両方の膨張が大きくなる条

件でのみ、変形量は大きくなる。つまり、W/P が小さくなると大きくなる。また、アスベストが3枚までは、枚数の増加とともに変形が大きくなるが、それ以上では変形量は変わらない。歯肉側マージンをアスベストに近づけて埋没すると変形は大きくなる。Dry アスベストがWet アスベストより変形が大きい。

アスベスト無の場合を除いて、その他の条件では、変形の形態は変わらない。