Polymerization Shrinkage and Contraction Force of Composite Resin Restorative Inserted with “Megafiller”

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This study quantified the contraction force and polymerization shrinkage of composite resins with / without β -Quartz Glass Ceramic Inserts (BQCI) as “Megafiller”. The materials used for the determination included a chemically cured composite and five light-cured composites. The system for measuring contraction force consisted of a transparent teflon tube for preparing the specimen, a small load cell, a dynamic strain gauge and a pen-recorder. After the composite was packed into the teflon mold, a BQCI (Type R3) was inserted through the opening and the specimen was cured. Linear polymerization shrinkage of the composites was measured every 10 seconds from the start of mixing or irradiation to 90 minutes by the mercury bath method. Three pieces each of BQCI (Type T3) were inserted in each specimen. The results suggested that BQCI was markedly effective in reducing polymerization shrinkage, but was not always effective in reducing the contraction force during polymerization.

Key words : Composites, Polymerization shrinkage, Glass inserts

INTRODUCTION

Composite resin restoratives require physical properties such as abrasion resistance and fracture toughness, long-term color stability, and adhesiveness to the tooth. The physical and optical properties have been markedly improved. However, composite resin restoratives themselves are not adhesive to the tooth, and a bonding agent at the interface between the tooth and the restorative is required. For long-term adhesiveness to the tooth, factors that inhibit adhesion should be eliminated in addition to improving the bonding agent. The major factors inhibiting adhesion include polymerization shrinkage and contraction stress during polymerization.

Polymerization shrinkage of composite resin is considered to be the primary cause of marginal gaps. In clinical practice, marginal adaptation of composite resin has been improved by the use of a bonding agent. However, when the contraction force associated with polymerization exceeds the adhesive force of composite resin to the tooth, gaps occur, and cavity sealing of the restoration is impaired. Ishikawa¹⁾ reported a negative correlation between the polymerization shrinkage rate and the filler content. In contrast, Tani²⁾ reported there was no correlation between the contraction force of composite resin and the filler content. Bowen³⁻⁶⁾ proposed a new clinical technique by which coarse granules of β -Quartz Glass-Ceramic Insert (BQCI) as “Megafiller” are added to the composite resin paste packed

in the tooth cavity. Therefore, we evaluated the effects of adding BQCI to composite resin on polymerization contraction force and the polymerization shrinkage rate.

MATERIALS AND METHOD

The materials used in this experiment included an auto polymerizing type and five photopolymerizing type resins (Table 1). The filler content of CF2 and RLX used for anterior teeth was 73-79 wt%, and that of P-50 and CPP for posterior teeth was 84-85 wt%. PEL and HMR for both anterior teeth and posterior teeth were submicron filler and microfiller types, respectively. β -Quartz Glass-Ceramic Inserts are available in three shapes ("R" round cylinder, "T" tapered cylinder, "L" shaped inlay) and three sizes (1, 2 and 3mm in diameter). All of the megafillers were pretreated with a silane coupling agent and showed a slightly wet surface due to silane-treatment. A small knob for holding with tweezers juts out on each megafiller. The shape and size of the megafiller were selected according to the size of the test specimen (Fig. 1).

Measurement of contraction force during polymerization

We developed a device²⁾ that measured the contraction force during polymerization using a small load cell * (10 kg-both for tension and compression). The force was converted by a dynamic strain gauge **, serially measured and recorded by a pen recorder # (Fig. 2). As shown in Fig. 3, at the packing site of composite resin, a teflon tube (inside diameter, 5 mm ; outside diameter, 6 mm ; length, 12 mm) was inserted into a stainless tube (5 mm in diameter) as a guide. A slit (4 mm) had been made on the side of the transparent teflon tube, and the composite resin paste was inserted via the slit (Fig. 4).

To prevent adhesive fracture due to shrinkage during polymerization of resin, propeller

Table 1 Composite resin restoratives tested

Code	Materials	Shade and Batch No.
CF2	Clearfil Fil ^{†1}	F U-1498 F C-1399
RLX	Restolux SP-2 ^{†2}	U 1154
P50	P-50 ^{†3}	U 1 E D 4 R
CPP	Clearfil Photo Posterior ^{†1}	U S 000002
PEL	Palfique Estelite ^{†4}	U E U 226
HMR	Heliomolar Radiopaque ^{†5}	U 360407

^{†1} Kuraray, Osaka, Japan

^{†2} Lee Pharmaceuticals, South El Monte, CA, USA

^{†3} 3M, St. Paul, MN, USA

^{†4} Tokuyama Soda, Tokyo, Japan

^{†5} Vivadent, Schaan, Liechtenstein

* LU-10KSB34D, Kyowa Electronic Instruments Co., Tokyo, Japan

** Strain Amplifier DPM-611A, Kyowa Electronic Instruments Co., Tokyo, Japan

LR 4210, Yokogawa Electric Corp., Tokyo, Japan

Fig. 1 β -Quartz Glass-Ceramic Inserts[®] used in this experiments. Type R3 for the contraction force measurement (right) and Type T3 for the polymerization shrinkage measurement (left).

Fig. 2 Device for the measurement of the contraction force.

Fig. 3 Schematic illustration of the packing site of composite resins in the device.

-shaped stainless holders were applied to the upper and lower surfaces of the test specimen. The cylindrical composite resin specimen had a diameter of 5 mm and a length of 5 mm. The autopolymerizing composite resin was inserted via the slit after 20-second mixing, and a BQCI^{##} (Type R3) (Fig. 1) was inserted into the resin. The time for inserting the composite resin and BQCI was within 1 minute and 40 seconds. Measurement started 2 minutes after the beginning of mixing and continued for 3 hours. The light-cured composite resin paste and BQCI were similarly inserted. Irradiation was performed using visible light sources[@]

^{##} Lee Pharmaceuticals, South El Monte, CA, USA

[@] Optilux, Demetron Research Corp., Danbury, CT, USA

from both sides for 60 seconds for polymerization. Measurement was started simultaneously with the beginning of light irradiation and continued for 3 hours. The volume of BQCI (Type R3) accounted for 15% of the volume of the composite resin specimen. For comparison, measurement was also performed in composite resin specimens without a BQCI and those with a teflon piece (3 mm in diameter) with the same size and volume as that of the BQCI (Type R3). All measurements were performed in a room at a constant temperature of 20°C with a constant relative humidity of 50%. The results are shown as the mean value of three measurements.

Measurement of polymerization shrinkage

Polymerization shrinkage was measured by the mercury bath method shown in Fig. 5. This procedure can be readily performed without restriction of the specimen.

Fig. 4 The packing site of the composite resin in the device (right), and a slit of the teflon tube and the direction of the insert (left).

Fig. 5 Schematic illustration of the mercury bath for measuring of the polymerization shrinkage of composite resins. R=Composite resin, G=Glass partition, S=Stainless steel plate, M=Magnet, In=BQCI (Type T3).

Autopolymerizing composite resin was attached to a partition in the mercury bath immediately after 20-second mixing. The other end was attached to a stainless steel plate to measure shrinkage. Measurement was started 1 minute 30 second after the beginning of mixing, and polymerization shrinkage was measured at 10-second intervals for 90 minutes. The light-cured composite resin paste was placed in the mercury bath. After starting measurement, irradiation was uniformly performed using a visible light source for 5 minutes. Three parallel pieces of BQCI (Type T3) were inserted into the composite resin paste (Fig. 5). The 3 BQCIs accounted for 31–38% of the volume of the composite resin specimen. For comparison, measurement was also performed in specimens without BQCI. Three specimens were measured for each material and condition.

RESULTS AND DISCUSSION

The contraction stress 3 hours after hardening is shown in Table 2. Figure 6 shows the contraction stress 1 minute, 1 and 3 hours after starting measurement. Insertion of BQCI did not affect and rather slightly increased the contraction stress during polymerization of the composite resin. Though the amount of matrix involved in polymerization shrinkage was decreased by insertion of BQCI, the composite resin may have strongly bound to the surface-treated BQCI and became stiff, resulting in a decrease in the flow that absorb contraction stress. CPP and P50 are highly loaded composite resins with an original filler content of 84 wt% or more. Even after BQCI was inserted, the total filler content including BQCI was not markedly changed. Therefore, the contraction stress may have been affected only slightly. However, the filler of HMR is a microfiller with a filler content 62 wt%. Insertion of BQCI may have increased the total filler content, also increasing polymerization contraction force. The elastic modulus may have increased with the increase of the filler content of the composite resin, and the contraction force may have increased with increases in the elastic modulus. Our results are in agreement with the results of Nemoto *et al*⁷⁾. In the specimens with an inserted teflon rod, contraction stress decreased with all materials. This may have been caused by detachment of the matrix resin on the interface, causing sliding.

The polymerization shrinkage was decreased by insertion of BQCI as shown in Table 3. The changes in the polymerization shrinkage of each of the composite resins for 3 hours from

Table 2 Contraction stress 3 hours after starting of measurement of composite resins with/without BQCI (MPa)

Materials	Glass ceramic inserts		Dummy *
	(-)	(+)	
Clearfil Fil	2.26(0.03)	2.46(0.03)	1.69(0.07)
Restolux SP-2	3.04(0.04)	3.36(0.11)	2.37(0.05)
P-50	3.52(0.21)	3.45(0.04)	3.17(0.12)
Clearfil Photo Posterior	4.31(0.15)	4.13(0.15)	3.63(0.09)
Palfique Estelite	3.22(0.08)	3.21(0.64)	2.38(0.16)
Heliomolar Radiopaque	2.48(0.20)	2.78(0.46)	1.54(0.06)

* Teflon Rod

() Standard Deviation

the beginning of polymerization are shown in Fig. 7-8. In particular, the decrease was 30-34% in HMR and CF2 with a relatively low filler content. Insertion of BQCI into composite resin effectively decreased the polymerization shrinkage but had only a slight effect on contraction stress during polymerization.

Fig. 6 Contraction stress 1 minute, 1 and 3 hours after start measurement.

Table 3 Polymerization shrinkage 90 minutes after strating of measurement of composite resins with / without BQCI

Materials	Glass ceramic inserts	
	(-)	(+)
Clearfil Fil	0.81(0.20) %	0.57(0.06) %
Restolux SP-2	0.63(0.02)	0.51(0.11)
P-50	0.40(0.01)	0.39(0.03)
Clearfil Photo Posterior	0.44(0.01)	0.27(0.05)
Palfique Estelite	0.55(0.04)	0.50(0.01)
Heliomolar Radiopaque	0.56(0.11)	0.37(0.06)

() Standard Deviation

Fig. 7 Changes in the polymerization shrinkage of composite resins with BQCI inserted.

Fig. 8 Changes in the polymerization shrinkage of composite resins without BQCI.

CONCLUSION

Contraction behavior of several composite resins inserted with β -Quartz Glass-Ceramic Inserts as “Megafillers” was determined in the study.

The results of this study suggest that β -Quartz Glass-Ceramic Insert was markedly effective in reducing polymerization shrinkage, but was not always effective in reducing contraction force during polymerization.

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チタン鑄造体表面下の鑄巣

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チタン鑄造体表面下の鑄巣の発生に関する耐火物について検討した。コンデンス法によって石英とクリストバライト粉末, および両者とマグネシア粉末の混合物を板状に成形し, 高温で焼成した。この焼成板を鑄型として得た鑄造体の断面を顕微鏡観察し, EPMA により分析した。石英の場合は, 鑄込みはほぼ完全で, 反応層は典型的な多層構造組織で, 鑄巣も少なかった。クリストバライトの場合はほとんどが鑄込み不良で, 網状の Ti-Si 相, クラック, および鑄巣からなる反応層が内部深くに広が

っていた。クリストバライトへのマグネシアの添加は鑄込み性を顕著に改善し, 反応層も石英の場合に見られる典型的な多層構造組織に変化した。しかし, 鑄型壁の方向に長細い鑄巣が α ケースの内側にほぼ等間隔に発生し, あたりは Si と Mg で汚染されていた。これはフォルステライトとチタンの反応によると考えられる。石英とクリストバライトの反応性の違いを焼成強度と結びつけることはできなかった。

Megafiller を充填したコンポジットレジン of 重合収縮挙動

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Bowen は, 歯の窩洞に填入したコンポジットレジンペーストの中に β -Quartz Glass-Ceramic Insert の粗粒を挿入するという新しい臨床技法, megafilled composite restoration を提案した。そこでわれわれは, glass insert を挿入したコンポジットレジンの重合収縮に与える効果を重合収縮力および重合収縮率の測定によって検討した。実験に用いた材料は, 常温重合型 1 種と光重合

型 5 種のコンポジットレジンである。実験の結果, glass insert を挿入することによってコンポジットレジンの重合収縮応力は変化しないか, むしろわずかながら大きくなる傾向を示した。重合収縮率については, glass insert の挿入によって小さくなることがあきらかになった。なかでもフィラー充填率の比較的低いコンポジットレジンでは, 30~34 % も小さくなることがわかった。

咬合を考慮したクラウン製作のための CAD の改良について

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前報で計測したデータに加え対合歯のバイトデータを追加して, 6 支台歯のクラウン補綴のための形状をデザインする CAD プロセスの改良を行った。まず歯冠データをバイトデータに対し中心咬合位になるように位置調整した。歯冠データを適正な位置に置いた後に対合歯の

FGP (機能咬合路) データによる咬合面の修正を行った。歯冠端部とマージンを結合するために, 前報で用いた B-スプライン関数の代わりに放物線関数を用いた。その結果, よりスムーズに連結した。このようにして支台歯データ, 歯冠データおよび連結部データからなる CAD デ