

The Quality of Post and Cores Made Using a Reduce-Time Casting Technique

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Clinical Relevance

The results of this study suggest that it is feasible to fabricate and deliver a quality cast post and core restoration in a single appointment using a phosphate investment with an abbreviated casting technique.

SUMMARY

Objectives: This study investigated the castability or casting completeness, surface roughness and dimensional accuracy of castings produced using a technique that requires as little as 24 minutes from the time of investment.

Methods and Materials: A total of 225 gold castings (45 per group) were fabricated using two standard and three accelerated casting proto-

cols. For each casting protocol, 15 castings were made from a rectangular, diamond-shaped mesh Duralay pattern to be used for castability evaluation; 15 castings were made from a flat, square pattern for measurement of surface roughness, and 15 castings were made from a tapered Duralay dowel to evaluate dimensional accuracy. Castings made with Fast Fire 15 and Ceramigold investment with shortened burnout times were compared to those made using Beauty Cast and Fast Fire 15 investment following the manufacturer's recommendations.

Castability was evaluated by counting the number of diamonds cast in a rectangular mesh. A profilometer was used to measure surface roughness. To check dimensional accuracy, the casting was replaced in the original mold and a traveling microscope was used to measure the size difference at 32x magnification.

Results: There were no statistically significant differences in castability and dimensional accuracy throughout all groups ($p>.05$). There was a

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statistically significant difference in the surface roughness of casts formed by Ceramigold compared to the other groups ($p < .001$).

Conclusion: The short casting time using Fast Fire 15 can produce post and core castings that are of a quality acceptable for clinical use.

INTRODUCTION

The process of casting metal restorations in dentistry was utilized as early as 1897, when Philbrook described the use of a casting procedure to produce a single tooth restoration.¹ In 1907, Taggart introduced a revolutionary casting procedure that is still used as a basis for restoration casting today. His protocol included fabrication of a direct wax pattern, investing the wax pattern, wax pattern burnout and casting gold into the space left by the wax pattern. Unfortunately, Taggart was unable to overcome the problem of metal shrinkage, which led to undersized restorations.² Subsequent research focused on ways to compensate for contraction of the metals during casting. Lane (1909) introduced mold expansion. He used investment with a higher percentage of silica, which gave it higher thermal expansion.³ However, the increased expansion of the investment did not completely compensate for the metal shrinkage. In 1910, Van Horn had the idea to expand the wax pattern and keep it expanded until the investment hardened.⁴ This eventually led to comprehensive studies by Weinstein and Coleman⁵ (1920s) at the United States National Bureau of Standards, where they studied the properties of waxes, investments and gold alloys used in casting. Other developments in casting techniques were the use of cristobalite and hygroscopic expansion. Phillips found that the use of a cristobalite-based investment would give a thermal expansion that would lead to more accurate castings.⁶ In 1932, Sheu introduced a hygroscopic technique, which used setting expansion of the investment to compensate for shrinkage of the gold.⁷ If the invested pattern was placed in water after an initial set, sufficient expansion occurred. In 1948, Hollenback resolved the coefficient of gold and gold alloy shrinkage, determining that the casting shrinkage of pure gold is 1.67 ± 0.02 percent.⁸

A cast metal post and core is often utilized when an endodontically-treated tooth requires coronaradicular stabilization to enhance the retention and resistance form of the definitive cast crown.⁹⁻¹² An advantage of the cast post compared to a prefabricated post is that the cast post requires less tooth instrumentation, which correlates with less tooth perforation.¹³ The cast post and core restoration also has the ability to resist rotational forces, which is not possible with a prefabricated post system.¹⁴⁻¹⁵ The popularity of prefabricated post systems is largely due to their ease of placement,

usually accomplished in one appointment with no lab involvement. This is compared to the cast post and core that requires at least two appointments and lab support. The standard method for casting involves a minimum of two hours of laboratory time: 10-15 minutes for spruing and investing, 30 minutes for investment setting time and a minimum of 75 minutes for staged burnout and casting.¹⁶ If a technique could be developed to reduce lab time from two hours to 30 minutes, the clinician could conceivably prepare a post space, form a pattern, cast and seat the cast post and core in one appointment. This would save the clinician and the patient valuable time. Campagni and Majchrowicz introduced an accelerated casting technique for custom posts and cores in 1991, which reportedly takes about 30-45 minutes and can be done while the patient waits in the office.¹⁷ Campagni's research showed that a conventional technique using a gypsum investment produced the best casting, followed by a phosphate bonded investment with a ring liner, then the accelerated technique using a phosphate bonded investment.¹⁷ In 1994, Bailey conducted research with an accelerated casting technique using phosphate-bonded investment materials (High-Temp, Ceramigold and Cera-Fina, Whip-Mix Corp, Louisville, KY, USA). The dimensions of the resulting castings increased by 0.11% to 4.80%.¹⁸ Bailey concluded that each investment performs differently, therefore, each investment should be evaluated before using with an accelerated technique.¹⁸

This study compared the quality of custom cast post and core restorations fabricated using various investment materials with a reduced-time casting technique.

METHODS AND MATERIALS

Patterns to be cast were fabricated from Duralay Inlay Pattern Resin (Reliance Dental Mfg Co Worth, IL, USA) according to the manufacturer's instructions. Each pattern was sprayed with Smoothex debubbler and wetting agent (Whip-Mix Corp) prior to investing. The patterns were invested in stainless steel casting rings measuring $1\frac{1}{2}$ " in diameter and $1\frac{3}{4}$ " in length (Degussa, Plainfield, NJ, USA) without ring liners using one of three investment materials: Beauty Cast, gypsum bonded investment (Whip-Mix Corp); Fast Fire 15, phosphate bonded investment (Whip-Mix Corp) or Ceramigold, phosphate w/carbon investment. (Whip-Mix Corp). All the investments were mixed following the manufacturer's recommendations. To serve as the controls, the bench setting and burnout times were according to the manufacturer's instructions for the Beauty Cast and Fast Fire 15-A groups. Accelerated casting protocols were utilized for the Fast Fire 15-B, Fastfire 15-C and Ceramigold groups (Table 1). Burnout for all the groups was done in an Accu-therm oven (Jelenko, Armonk, NY, USA). The castings were

Table 1: Casting Investments and Burnout Times					
Investment	Investment Type	Burnout Protocol	Investment Setting Time	Burn Out Temperature °F	Time at Max Temp
Beauty Cast	Gypsum Bonded	Manufacturer Recommended	30 minutes	75-1200 inserted into room temperature oven	30 minutes
Fast Fire 15-A	Phosphate Bonded	Manufacturer Recommended	15 minutes	1300 inserted into max temperature oven	30 minutes
Fast Fire 15-B	Phosphate Bonded	Accelerated	15 minutes	1300 inserted into max temperature oven	15 minutes
Fast Fire 15-C	Phosphate Bonded	Accelerated	12 minutes	1650 inserted into max temperature oven	12 minutes
Ceramigold	Phosphate Bonded with Carbon	Accelerated	15 minutes	1300 inserted into max temperature oven	15 minutes

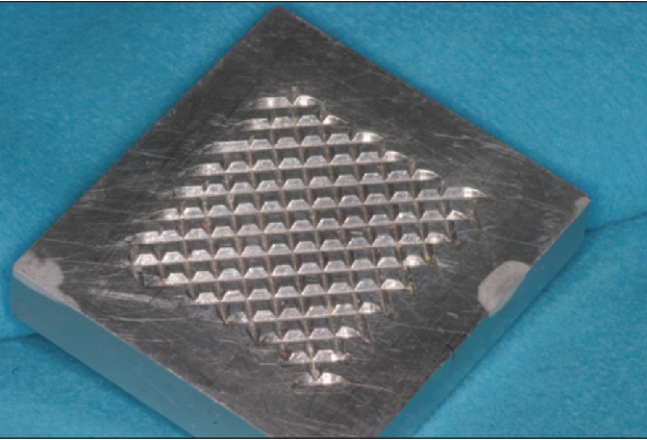


Figure 1. Aluminum mold for fabricating the Duralay patterns to produce castings for castability evaluation.

made using a broken-arm casting machine (Model 74 Exac-U-Cast, Handler, Westfield, NJ, USA) wound three times in a clockwise direction. New Ney-Oro B-20 type III gold (Ney International, Bloomfield, CT, USA) was placed in a crucible mounted in the casting machine and heated with the reducing flame of a natural gas/oxygen torch (Melting Torch for gas/air model 310920, Degussa Corp, Plainfield, NJ, USA). Approximately 0.01 grams of Ney casting flux (Ney International, Bloomfield, CT, USA) was sprinkled onto the molten metal. The casting ring was removed from the burnout oven and placed in the cradle of the casting machine. The casting arm was then released, allowing the machine to centrifuge gold into the mold. After two minutes of air-cooling, the casting ring was quenched in a cold water bath.

A total of 225 castings were fabricated in the current study. Three types of castings were made using each casting protocol: 15 castings to evaluate castability or the ability to fill a mold, 15 to test surface roughness

and 15 to assess dimensional accuracy.

Castings used to evaluate castability were made from rectangular-shaped mesh Duralay patterns. Each pattern measured 2 cm × 3 cm × 0.75 mm thick. The meshwork consisted of 55 diamonds, each measuring 2 mm × 2 mm. The patterns were formed using an aluminum block with V-shaped crisscrossing grooves (0.75 mm wide × 0.75 mm deep) machined into its surface (Figure 1). Duralay was mixed and poured into the mesh mold. Excess resin was scraped away. Once set, the pattern was removed from the mold and trimmed to the proper dimensions. The pattern was placed on a sprue base (Figure 2), so that the end of the pattern was 6 mm away from the end of the casting ring. Six penny-weights of gold were used to cast each pattern. After removal from the investment, the castings were air abraded with 25 µm aluminum oxide beads (Danville Engineering, Ramon, CA, USA) and placed in a hot pickling solution (JEL-PAC, Jelenko, Armonk, NY, USA). Castability was determined by counting the number of diamonds cast in the rectangular matrix. If a diamond was not completely cast, it was not counted.

Castings for measuring surface roughness were fabricated from a square, flat Duralay pattern measuring 1.5 cm x 1.5 cm, with a thickness of 2.5 mm. The mold



Figure 2. Casting produced to evaluate castability of the Duralay pattern. A rectangular-shaped matrix was evaluated for the number of diamonds cast.



Figure 3. Casting produced to evaluate the surface roughness of the casting. This is a square pattern measuring 1.5 cm in length, made against a glass slab.



Figure 4. Casting produced to evaluate dimensional stability. This casting is produced from a 10 mm pattern that is 2.5 mm wide at the base and 2.0 mm wide at the apex. This produced a tapered casting.

was preset with a stylus force of 200 mgf/2mN, a probe range of $\pm 50 \mu\text{m}$ and a drive speed of 0.25 mm/seconds. The results were reported in Ra's, the arithmetic average of the absolute values of the measured roughness profile height deviations taken within the length measured in micrometers.

The dimensional accuracy of each casting protocol was evaluated by measuring the fit of cast dowel posts in a tapered hole machined through a 10 mm-thick

used to fabricate the Duralay patterns was prepared by cutting a square hole in a sheet of Triad visible light-cured urethane dimethacrylate material (Dentsply International, York, PA, USA). The Triad material was then placed on top of a glass slab and light cured. Duralay was mixed and placed into the mold against the glass slab and allowed to set. The pattern was removed from the mold and trimmed to the proper dimensions without disturbing the smooth surface formed by the glass slab. The pattern was sprued at the corner (Figure 3) and positioned so the edge of the pattern was 6 mm from the top of the casting ring. Ten pennyweights of gold were used to cast each pattern. After removal from the investment, the castings were cleaned with hydrofluoric acid (Stripping Acid, American Dental Supply Inc, Easton PA, USA). The surface roughness was measured with a profilometer (Surfanalyzer 5000 Analysis System, Deterco, Inc, Houston, TX, USA) over an 8 mm transverse length of the smooth surface of the casting. The instrument

stainless steel block (Figures 4 and 5). The diameter of the hole measured 2.5 mm and 2 mm on the top and bottom surfaces of the block, respectively. The hole was used as a mold to fabricate acrylic dowel patterns. The sides of the hole were lightly coated with mineral oil and the excess was removed with a gentle air spray. The block was then placed, small-hole side down, on a glass slab. Duralay acrylic was mixed according to the manufacturer's instructions and introduced into the mold. A small diameter plastic sprue lightly coated with Duralay monomer was inserted into the hole to eliminate voids and reinforce the acrylic. Excess material was cleared away and the pattern was allowed to set. The remaining acrylic flash was removed and the pattern was separated from the mold. The pattern was inspected for voids and reinserted into the mold to confirm a precise fit. The pattern was sprued on the large end and positioned so that the end of the pattern was 6 mm from the top of the casting ring. Four pennyweights of new gold were used to cast each dowel post. After removal from the investment, the castings were cleaned with Stripping Acid. They were evaluated for casting nodules under a 6x-magnification microscope (Swift Instruments, Boston, MA, USA), and the nodules were removed with a #2 round bur. The castings were fit back into the stainless steel mold to measure dimensional accuracy. They were seated with half a turn, while applying 50 grams of pressure. If the post extended beyond the lower surface of the mold, it scored a negative value, meaning that the casting was smaller than the original pattern. If the end of the post stopped short of the lower surface of the mold, it scored a positive value, meaning that expansion had occurred. The length difference between the end of the post and the lower surface of the mold was measured using a traveling microscope (Gaertner Scientific Corporation, Skokie, IL, USA) at 32x magnification. When the post extended beyond the mold, the difference was meas-



Figure 5. The dimensional stability casting is placed back into the stainless steel pattern former to evaluate casting and dimensional changes from the original Duralay pattern. The casting passes through the pattern former, indicating shrinkage in the size of the pattern.

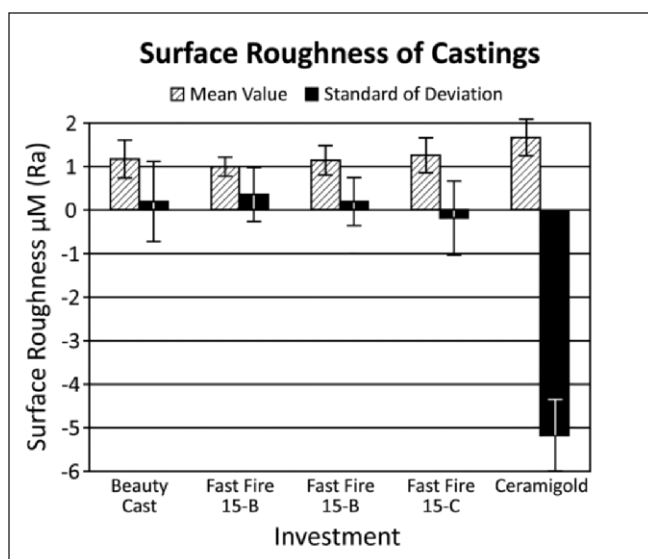


Figure 6. Surface roughness of castings.

ured directly. However, when the post stopped short of the lower surface of the mold, an indirect measuring technique became necessary. A vinyl polysiloxane impression (Reprosil, Dentsply International) was made of the unfilled mold space. The impression was then measured using the microscope. Each measurement was taken three times, with the average measurement being recorded in millimeters; this measurement gave a numeric value for the dimensional change.

Data Analysis

The data were analyzed using descriptive and inferential methods. Castability for each of the investment techniques was assessed using descriptive methods only. Data on surface roughness and dimensional change were analyzed using a one-factor ANOVA with

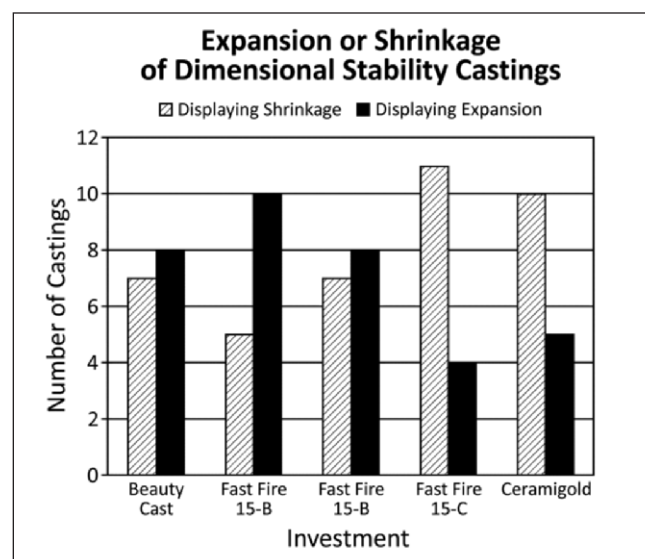


Figure 7. Expansion or shrinkage of dimensionally stable castings.

Tukey post hoc analysis for pairwise comparisons. Data on dimensional accuracy were subsequently dichotomized into samples that experienced either shrinkage or expansion and frequencies were analyzed using chi square analysis.

RESULTS

Castability: All samples cast completely, regardless of the casting protocol used. **Surface Roughness:** One-factor ANOVA showed a statistically significant effect ($p < .0001$) of investment type on the surface roughness of the castings, with the Ceramigold group being significantly rougher than all the other groups (Table 2 and Figure 6). A computed eta square value of 0.285 suggests that the effect of investment on smoothness of the cast was large.

The Fast Fire 15-C and Ceramigold protocols produced finning in approximately 50% of the castings. One mold blew up in the burnout oven, leaving only 14 specimens of the Ceramigold group for surface roughness evaluation. **Dimensional Accuracy:** ANOVA showed no statistically significant differences in dimensional accuracy among the investment groups, though variability was great for all groups evidenced by the large standard deviations. Fast Fire 15-A produced more castings with expansion, followed by Fast Fire 15-B and Beauty Cast. The Fast Fire 15-C castings exhibited the least number of expanded castings (Table 3) and (Figure 7).

Investment	Surface Roughness µm (Ra) Mean Value	Surface Roughness µm (Ra) Standard of Deviation
Beauty Cast	1.17 (.44)	0.20 (.92)
Fast Fire 15-A	1.00 (.22)	0.35 (.62)
Fast Fire 15-B	1.14 (.34)	0.20 (.55)
Fast Fire 15-C	1.26 (.40)	-0.18 (.85)
Ceramigold	1.67 (.42)	-5.17 (.82)

Investment	Number of Castings Displaying Shrinkage	Number of Castings Displaying Expansion
Beauty Cast	7	8
Fast Fire 15-A	5	10
Fast Fire 15-B	7	8
Fast Fire 15-C	11	4
Ceramigold	10	5

Chi square analysis of this frequency distribution showed no significant difference in acceptability ($p=.169$, $\chi^2 = 6.43$) among the groups.

DISCUSSION

All casting patterns were made with Duralay methyl methacrylate resin. Duralay is commonly used for post and core fabrication and is dimensionally stable once the auto polymerizing reaction is complete.¹⁰

Pilot testing was used to determine the casting protocols used in the current study. Each casting pattern was attached to a sprue former and positioned 6 mm from the end of the casting ring. Locating the patterns closer than 6 mm to the end of the ring resulted in gold exploding out the end of the ring during casting or finning of the restoration due to investment breakdown. The minimum set time for the investment after pouring into the casting ring was 12 minutes. The investment exploded in the oven upon heating to 1200°F when the setting time was reduced to 10 minutes. To achieve complete burnout of the resin patterns, the minimum burnout times were determined to be 12 minutes at 1650°F and 15 minutes at 1300°F.

The castings for surface roughness testing obtained from the Ceramigold and Fast Fire 15-C groups displayed finning, likely a result of mold breakdown due to premature and rapid heating.¹⁹ Though impossible for the profilometer to traverse these fins, adequate surface area was available between the fins to perform surface roughness measurements. Interestingly, the finning displayed on these castings was not observed on the cast posts fabricated for measuring dimensional accuracy. This may have been due to the smaller patterns and less bulk of gold used to make the posts compared to the much larger surface roughness castings. The Ceramigold castings displayed statistically greater surface roughness than castings from the other four investment groups. Normally, a smooth restoration is preferred, as surface roughness can inhibit complete seating of the restoration and may accumulate plaque, negatively impacting the health of periodontal tissues.²⁰ This may not be the case with the cast post and core. Studies show that a serrated or roughened post is more retentive than a smooth one.¹⁹ Therefore, the rougher castings of the Ceramigold group may be acceptable. It should be noted that the increased surface roughness did not seem to affect the fit of the posts from the Ceramigold group during the dimensional accuracy portion of this study.

Dimensional accuracy is critical when fabricating cast posts. Intracoronar restorations, such as inlays and cast post and cores, need to be slightly smaller to prevent unnecessary stress on the tooth.^{9,20} Therefore, when fabricating a custom post and core, either the exact size or a slightly undersized casting is desired. One way to

achieve this is to invest the pattern in a metal ring without placing a ring liner. A ring liner is compressible, allowing the investment to expand outward as it sets. Without a liner, outward expansion of the setting investment is limited by the rigid walls of the casting ring, causing compression of the pattern. This can completely eliminate the effect of setting expansion.²¹ Shillingburg states that omitting the ring liner or increasing the investment water-powder ratio by 1 ml results in a slightly undersized casting that will fit more easily into the tooth preparation.¹⁰ Another factor that can affect the dimensions of the casting is thermal expansion of the metal casting ring. Casting rings can be made of various materials, with thermal expansions ranging from 0.95% to 1.40% for iron and brass, respectively. A casting ring exhibiting less thermal expansion is more likely to result in an undersized casting. Ray noted when casting inlay patterns use an asbestos liner, stainless steel with a thermal expansion of 1.2% proved to be the most compatible casting ring.²² In this investigation, all castings were made using stainless steel casting rings without liners. However, omitting the ring liner did not always result in an undersized casting (Table 3 and Figure 7). There was no statistical difference in dimensional accuracy among the test groups. All groups showed considerable variability, with each producing both over- and under-sized castings.

CONCLUSIONS

The results of the current study suggest that it is possible to produce clinically acceptable cast posts using Fast Fire 15 and Ceramigold investments following accelerated casting protocols. The Fast Fire 15 accelerated protocols produced castings of a quality equal to the Beauty Cast and Fast Fire 15 standard protocols. The Ceramigold castings fit as well as the other castings, but they displayed greater surface roughness. Additional studies are needed to determine procedures that will consistently produce undersized castings.

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