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RETROSPECTIVE CLINICAL EVALUATION OF 1,314 CAST GOLD RESTORATIONS IN SERVICE FROM 1 TO 52 YEARS

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The contemporary clinician and patient are faced with a bewildering number of options of dental materials for the restoration of posterior teeth. Treatment choices should be based on valid scientific evidence related to the likely prognosis and life span of the therapy, anticipated benefits and risks, costs, esthetic considerations, and personal preferences of both the patient and the dentist. Unfortunately, the evidence base for posterior dental restorations is less than optimal. It is generally believed by clinicians that properly fabricated cast gold restorations provide excellent longevity and that esthetic (tooth-colored) alternatives have a predicted span of service that may be considerably shorter. However, the evidence supporting these assumptions is not as convincing as is commonly believed. This study was undertaken to evaluate the long-term success rate of a large number of cast gold restorations placed by a single dentist in the private practice setting. Most of the restorations evaluated had been in service for many years, and 72% had been in service for 20 years or more.

LITERATURE REVIEW

Until recently, occlusal stress-bearing restorations in posterior teeth were primarily fabricated from either silver amalgam or cast gold. Amalgam has proven to be an extremely cost-effective material owing to its inherent direct placement and its self-sealing capacity.[1] One excellent study of this material determined that the survival rate of large multisurface amalgam restorations was > 90% at 10 years.[2]

Many clinicians have noted anecdotally that cast gold restorations have an exceptional record of longevity; however, the scientific literature is, at best, equivocal in this

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respect. Some studies have revealed relatively disappointing results with cast gold,[3,4] whereas others have demonstrated excellent survival rates.[5–8] This variability in survival rates is likely the result of differences in study design, operator variability, and patient-related factors, such as differences in diet, oral hygiene practices, caries susceptibility, and parafunctional habits.

One short-term study of Class II cast gold inlays reported a failure rate of 17% at 3 years,[3] whereas another reported a 50% failure at 7 years.[4] A study evaluating outcomes of restorative therapy done in a dental school clinic reported 10-year survival rates of 91% for cast gold restorations, 72% for silver amalgams, and 56% for composite resin restorations.[5] One study that focused on reasons for replacement of cast gold restorations found the mean age for failure was 18.5 years (range 5–41 yr) and that the mean age of successful, functioning cast gold restorations was between 15 and 16 years.[6] The authors concluded that the longevity of cast gold restorations exceeds that of available alternatives by a factor of two or four, and thus concluded that cast gold is clearly a cost-effective material.

Another retrospective study of cast gold inlays and partial veneer crowns done in a dental school clinic found that the mean survival rate of 3,518 cast gold restorations was 85.7% at 10 years.[7] Survival rates of specific types of restorations varied from a low of 76.1% for occlusal inlays to rates of 88.3% for mesio-occlusal inlays, 87.5% for mesio-occlusodistal inlays, and 86.1% for partial veneer crowns. This study made no attempt to evaluate the quality of the restorations.

A recent study developed criteria for evaluation of cast gold restorations, and evaluated 303 cast gold restorations placed either in a dental school clinic or two private practices.[8] The mean age of the restorations was 18.7 years, and 86% of the restorations had been in the mouth 15 years or more. The overall failure rate at that time (18.7 yr) was 13.8%. Kaplan-Meier survival estimates were calculated and indicated a survival rate at 10 years of 96.1%, at 15 years of 92.2%, at 20 years of 87.0%, and at 30 years of 73.5%. Results from this study indicate that the longevity of cast gold restorations can be excellent.

METHODS AND MATERIALS

A random review of charts in the private dental office identified 120 patients who had multiple cast gold restorations placed at least 10 years previous to the examination date. All of the patients had been treated by one dentist (R.V.T.) between 1946 and 2001. Invitations were sent asking patients to participate in a noninvasive examination. Patients were told that their restorations would be evaluated and that clinical photographs of the restorations would be taken.

Letters were sent to the addresses of record of all 120 identified patients. Four of these letters were returned either because the patients were deceased or because of incorrect addresses. One respondent was willing to be examined but was unavailable at the examination times. The remaining 115 patients responded and made appointments for the examination. One appointed patient did not present for evaluation owing to severe weather conditions. Thus, the total number of patients evaluated was 114.

Of the 114 patients who reported for examinations, 39 (34.2%) were male and 75 (65.8%) were female. The mean age of the patients was 67.8 years, ranging from 31 to 91 years. Evaluations were done using modified United States Public Health Service (USPHS) criteria (Table 1) by one evaluator and then reevaluated by two investigators using magnified high-quality digital photographs that were taken of all evaluated restorations at the examination appointments. When the evaluation of the digital photographs differed from the clinical evaluation, the lowest evaluation was chosen.

Chart reviews were done prior to patient examination, and placement dates and restoration types were noted. For those restorations that had been replaced, date of

TABLE 1. CRITERIA FOR EVALUATION OF CAST GOLD RESTORATIONS.*

I. Marginal adaptation
- A. Margin not discernible; explorer does not catch; no visible discoloration
- B. Explorer catches margin, but no visible opening
- C. Gap or chipping with dentin or liner exposed; distinct discoloration visible; secondary caries
- D. Partial fracture; fracture; loose restoration; fracture of abutment tooth

II. Anatomic form
- A. Correct contour with tight proximal contacts (floss); no wear facets on restoration of opposing teeth
- B. Slightly under- or overcontoured; weak proximal contact; small wear facets on restoration or opposing teeth (< 2 mm)
- C. Distinctly under- or overcontoured; missing proximal contact; large wear facets on restoration or opposing teeth (> 2 mm)

III. Surface texture
- A. Smooth, glazed, or glossy surface
- B. Slightly rough or dull surface
- C. Surface with deep pores, rough, or unevenly distributed pits; cannot be refinished

IV. Miscellaneous
- C. Primary caries; requires endodontic therapy; requires periodontal therapy; extraction or additional restorative therapy

United States Public Health Service criteria adapted from Studer SP et al.[8]
*Restorations with an *A* or *B* rating are considered successful. Those rated *C* or *D* are considered failures.

replacement and length of service of the restoration were noted. A restoration was deemed a failure if it had been replaced or if one or more of the USPHS criteria were evaluated at a *C* or *D* level (see Table 1).

A total of 1,314 restorations were evaluated, 636 in maxillary teeth, 678 in mandibular teeth. Seven hundred six of the restorations were placed in molars, 530 in premolars, and 78 in canine teeth. The time of service for the restorations ranged from 1 to 52 years (Table 2). Almost 90% of the restorations had been in place for at least 10 years, 72% had been in the mouth 20 years or more at the time of evaluation, and 45% had been in service from 25 to 52 years.

TABLE 2. NUMBER OF RESTORATIONS AND TIME OF SERVICE.

	Time of Service (yr)					
Restorations	**1–9**	**10–19**	**20–24**	**25–29**	**30–39**	**40+**
Number (*N* = 1,314)	132	236	356	346	227	17
% of total	10.05	17.96	27.09	26.33	17.28	1.29

TABLE 3. NUMBER AND TYPES OF CAST GOLD RESTORATIONS.

Restoration Type	Number (*N* = 1,314)	% of Total
Inlays	644	49
Onlays	197	15
Partial veneer crowns	118	9
Full veneer crown	355	27

Forty-nine percent of the evaluated restorations were inlays, 15% were onlays, 9% were partial veneer (three-quarter or seven-eighth) crowns, and 27% were complete veneer crowns. Inlay/onlay restorations were recorded as onlays (Table 3).

To minimize the invasiveness of the examination, radiographs were not taken, but the bite-wing radiographs had been taken for the majority of the patients within 2 years prior to the examination. Given the age of most of the restorations and the low caries rates demonstrated by the majority of the patients, this was deemed adequate.

RESULTS

The number of restorations evaluated, their years in service, and

TABLE 4. RESTORATION TYPE AND YEARS OF SERVICE.

Time of Service (yr)	Inlays (n = 644)	Onlays (n = 197)	Partial Veneers (n = 118)	Full Veneers (n = 355)
1–9 (n = 132)	57	13	10	54
10–19 (n = 236)	113	33	16	76
20–24 (n = 356)	164	49	39	104
25–29 (n = 346)	191	54	29	69
30–39 (n = 227)	102	48	24	52
40+ (n = 17)	17	0	0	0

restoration type are displayed in Table 4. The total number of restorations that required replacement in the patients who were evaluated was 60 of 1,314. This translates into 95.4% success or 4.6% failure rates, depending on the viewer's perspective. The number and percentage of failures as a function of time are presented in Table 5. It is important to note that exponentially greater numbers of failures do not occur over time. Although a small number of failures occurred in each time group, the failure rates in the older restoration groups are actually lower than those in the 10- to 19-year group.

The earliest restoration loss occurred at 7 years, and the mean time of service for the restorations that needed to be replaced in the six groups was 8, 15.9, 21.5, 26.1, 33.8, and 41 years, respectively.

The number of failures as a function of restoration type is presented in Table 6. Note that the failure rates are generally quite low. Although there are differences in the failure rates among the different types, variability in case selection, amount of tooth structure remaining, and patient variables such as parafunctional habits and oral hygiene preclude the drawing of any conclusions as to the superiority of any type of restoration over any other. Inlays had a failure rate of 4.7%, onlays 3.0%, partial veneer crowns 8.5%, and full veneer crowns 3.9 %.

The failures related to the types of restoration and time of service are presented in Table 7. Note that only 4 failures of 132 restorations occurred in years 1 to 9, with the earliest failure recorded at 7 years.

TABLE 5. FAILED RESTORATIONS AS A FUNCTION OF TIME.

	Time of Service (yr)					
Years	1–9	10–19	20–24	25–29	30–39	40+
Restorations (N = 1,314)	132	236	356	346	227	17
Failures (n = 60)	4	23	18	7	7	1
Success rate (%)	97	90.3	94.9	98	96.9	94.1

TABLE 6. FAILURE RATES RELATED TO RESTORATION TYPE.

Type of Restoration	Total Placed	Failures	% Failed
Inlays	644	30	4.7
Onlays	197	6	3.0
Partial veneers	118	10	8.5
Full veneers	355	14	3.9

All restorations were evaluated for marginal integrity, anatomic form, and surface texture. The data of the analysis are presented in Table 8. Overall, the restorations were excellent in every respect, and 96% of the evaluations were rated alfa. Only three restorations were identified as needing replacement, one because of an open margin with recurrent caries after 26 years of service, and two because of cuspal fracture after 27 and 30 years of service.

DISCUSSION

Perhaps the most interesting finding in this study is the astonishing level of voluntary participation by the patients. Almost 100% of the patients contacted were willing to travel to the office for evaluation, and 114 of 116 (98.3 %) patients contacted were actually examined. This speaks volumes in the area of practice management, and perhaps lends validity to the age-old concept that the optimum method of developing a loyal practice base

TABLE 7. FAILED RESTORATIONS RELATED TO TIME AND TYPE OF RESTORATION.

	Time of Service (yr)					
Restoration Type	**1–9 (*n* = 132)**	**10–19 (*n* = 236)**	**20–24 (*n* = 356)**	**25–29 (*n* = 346)**	**30–39 (*n* = 227)**	**40+ (*n* = 17)**
Inlays	2/57	11/113	9/164	3/191	4/102	1/17
Onlays	0/13	2/33	4/49	0/54	0/48	0/0
Partial veneers	1/10	4/16	1/39	3/29	1/24	0/0
Full veneers	1/54	6/76	4/104	1/69	2/52	0/0

over time is to provide quality oral care for patients.

The strength of the study lies in the numbers and longevity of the evaluated cast gold restorations. One thousand three hundred fourteen restorations were evaluated, and the survival rate was 95.4%. Considering that 72% of the restorations had been in the mouth at least 20 years, this is an impressive number.

It is worth noting that the evaluation of the restorations was done by independent evaluators who did not fabricate or place the restorations. The clinical evaluations of the restorations were universally high. It is clear that this was an evaluation of extremely high-quality cast gold restorations. Although it would be inappropriate to suggest that all cast gold restorations can anticipate this specific success rate, it is safe to conclude that properly fabricated cast gold restorations can indeed provide exceptional long-term performance.

The study also has several obvious deficiencies. All of the restorations were placed by one dentist, and it can be argued that the results achieved cannot be extrapolated to a broad spectrum of general dentists. However, it can also be argued that the preparations and techniques used to fabricate the cast gold restorations evaluated in the study have been published for many years and are well established in the dental community.[9] For several decades these procedures have been taught successfully to many general dentists worldwide through over 50 established R.V. Tucker cast gold study clubs.

The study is retrospective in nature, which inherently weakens its power. Most of the failures reported were the result of replaced restorations, and the causes of failure and need for replacement were not known to the investigators. Thus, no data on reasons for failure are reported. There are also no control populations with the study.

Although all evaluations were done by one investigator, the validity of the evaluations was increased by a secondary evaluation using magnified high-quality digital photographs.[10] Although patient selection was not completely randomized, the first 120 patients identified as having multiple cast gold restorations over 10 years of age were accepted, and no patients were omitted owing to specific exclusion criteria.

The nature of the study makes it impossible to determine what factors may have contributed to the very high documented success rates. The patients certainly seemed to experience a "normal" caries rate relative to the times of placement of the restorations and averaged 11.5 cast gold restorations per patient. This does not include other types of restoration and indicates that a highly caries-resistant population was not recruited for this study. All castings were cemented with zinc phosphate cement, which is currently not in favor with many

TABLE 8. CLINICAL EVALUATION OF CAST GOLD RESTORATION.

Evaluation	Alfa	Bravo	Charlie	Delta
Marginal integrity	1,251	62	1	0
Anatomic form	1,274	38	1	1
Surface texture	1,234	80	0	0

contemporary clinicians. It has been speculated that even higher success rates may have been achieved with improved contemporary luting agents.[11]

Given the current preoccupation with esthetics and tooth-colored restorations, these demonstrated long-term survival rates must be viewed in context with the short-term expectations of esthetic tooth-colored alternatives. It should be noted that 49% of the restorations placed in this study were inlays, which can often provide an extremely acceptable esthetic result in posterior teeth. The failure rate with inlays was 4.6% over the long time frame (almost 90% of the restorations had been in service at least 10 years) of this investigation. Many cast gold restorations on molars are not visible at conversational distance and thus can be considered for use with many patients.

Conversely, neither clinical experience nor the dental literature indicates that indirect tooth-colored alternatives for posterior teeth provide a predictable long-term restorative option for patients. There is a paucity of literature related to the long-term survival of laboratory fabricated composite resin inlays. One study evaluated results of Concept® laboratory-processed composite resin inlays versus cast gold inlays at 7 years.[12] The study concluded that at 7 years, the Concept system yielded clinically acceptable restorations. A careful perusal of the article reveals that

Figure 1. These cast gold restorations had been in service from 25 to 32 years.

33% of the Concept restorations were missing after 7 years, and that the failure rate in molars was close to 50% at that time. That success rate pales in comparison with the results of this current study (97% at 9 years).

Ceramic inlays and onlays have received considerably more attention in the literature, and the results, although mixed, are more encouraging. Five-year survival rates of ceramic bonded restorations range from a low of 76% in one study to acceptable rates of 95 to 96% in others.[13–20] However, careful reading of these investigations creates cause for concern. There does appear to be a high incidence of marginal ditching with bonded ceramic restorations. This can be progressive and is clearly related to the prebonding marginal gap. The poorer the prebond gap, the greater the marginal ditching.[21] More importantly, this marginal ditching is often associated with microcracks in the ceramic restoration that are highly likely to propagate over time and result in premature failure of the restorations. The wisdom of restoring the entire posterior dentition of patients with unproven bonded ceramic restorations in the name of esthetics or occlusal rehabilitation to some imagined optimal maxillomandibular position must be questioned.

The choice of restoration for posterior teeth has become complex with the wide variety of restorative options that exist today. The clinician and patient must consider a number of variables before

Figure 2. These cast gold restorations had been in service from 10 to 15 years.

making a decision. Although esthetics is unquestionably a major consideration for most patients, two important variables are clearly predictability and longevity.[22–25] Cast gold restorations have been available since 1907 when Taggert introduced the lost-wax process to dentistry.[26] The cavity preparations and techniques essential for success have been studied and evaluated for years and are well known and can easily be learned.[27] Conversely, the indirect tooth-colored options are recent innovations, and the cavity preparations and technical procedures for success are not known at this time and have yet to be delineated through scientific investigations.

The literature indicates that these tooth-colored restorations provide a significantly shorter life span than does cast gold. The evidence presented in this article indicates that properly fabricated cast gold restorations can provide extremely long-term restorative service. It has been speculated that perhaps the esthetic dentistry pendulum has swung too far.[28]

Before making treatment recommendations for patients, clinicians must perform an esthetic analysis to determine the patients' esthetic expectations and also to evaluate the dental display to determine what is visible at conversational distance with both a normal and exaggerated smile.[29–32] For many patients, cast gold inlays can be used to restore decayed or previously restored teeth with predictable longevity and no real negative impact on esthetics. Similarly, many molar teeth are not visible, even with exaggerated smiles, and can

Figure 3. These cast gold restorations had been in service from 22 to 25 years.

optimally be restored with no esthetic impact with cast gold inlays, onlays, partial veneer crowns, or full veneer crowns. Placing bonded ceramic inlays and onlays in mandibular and maxillary second molars is an unnecessary exercise in risk management.

The contemporary clinician should offer patients a substantial menu of posterior restorative services. This menu should include silver amalgam, cast gold, direct composite resin, indirect tooth-colored materials, and complete veneer crowns. Limiting the patients' choice to metal-free materials is not rational and deprives the patient of many valuable restorative options.[33] Clinicians must understand that the term *esthetics* is not synonymous with *tooth colored*. Most patients request esthetic dentistry, and, of course, do not want restorations that display metal. However, they do not request metal-free dentistry and will gladly accept metal restorations that do not display metal in return for longevity.

Patients deserve the best dentistry has to offer, and clearly must provide the clinician with adequate informed consent. Once they understand the advantages and disadvantages of the various restorative options, they can choose a restoration that best matches their preferences. It is postulated that both tooth-colored indirect restoratives and cast gold are viable options that can serve patients well, depending upon their needs and desires.

SUMMARY AND CONCLUSIONS

A retrospective clinical evaluation of 1,314 cast gold restorations in 114 patients placed by one

Figure 4. These cast gold restorations had been in service from 29 to 35 years.

practitioner was conducted. A very high percentage of patients contacted (114/116 [98.3%]) participated in the evaluation. Almost 90% of the restorations had been in service for over 9 years, 72% for over 20 years, and 45% from 25 to 52 years. All restorations had been cemented using zinc phosphate cement. The restorations were evaluated by independent evaluators in terms of marginal integrity, anatomic form, and surface texture, and 96% of the evaluations were excellent (Figures 1–5).

Sixty restorations required removal and replacement, yielding an overall failure rate of 4.6% or a survival rate of 95.4%. The survival rates at various time periods were 97% at 9 years, 90.3% at 20 years, 94.9% at 25 years, 98% at 29 years, 96.9% at 39 years, and 94.1% for restorations in place > 40 years.

It appears that properly fabricated cast gold inlays, onlays, partial veneer crowns, and full veneer crowns can provide extremely predictable, long-term restorative service. It is suggested that the use of such restorations should not be automatically precluded simply because they are gold colored. These restorations should be considered in patients who are more concerned with longevity than esthetics, and in those patients in whom placement of a conservative cast gold restoration would not result in an unesthetic display of metal.

DISCLOSURE

The authors have no financial interest in any of the companies

Figure 5. These cast gold restorations had been in service from 18 to 27 years.

whose products are mentioned in this article.

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