# Clinical performance of three anterior restorative materials over 10 years

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*The long-term performance of two chemically activated composite resins was compared to that of one silicate cement. Bulk and cavosurface marginal discoloration was evaluated with both an indirect photographic method and the direct US Public Health Service evaluation system. The results confirmed that composite resins had superior performance but higher secondary caries incidence than did silicate cements. The macrofilled composite resins showed better clinical performance than the microfilled restorations, as well as similar incidences of bulk and marginal discoloration. The agreement between the scores obtained with the direct evaluation criteria and those resulting from the indirect evaluation method was relatively poor. The indirect scores were usually the same or poorer than the direct clinical scores. The results indicated that the clinical evaluation may be the least sensitive of the two methods. The discrepancy in the scorings may, on the other hand, signify that the indirect photographic method records reflectance spectra that are not normally obtained in vivo.*
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## Introduction

Despite the nearly universal use of composite resins as a restorative material for anterior teeth, there are few data on the long-term clinical performance of restorations of contemporary composite resin systems in such situations.[1] The present study aimed to compare the long-term clinical performance of two chemically activated composite resins to that of one silicate cement.

Two basically different approaches to clinical assessments are commonly used in dental materials research, ie, direct and indirect techniques.[2] The most commonly used direct technique is the US Public Health Service (USPHS)[3] evaluation system, and many clinical studies have reported restoration discoloration according to the USPHS criteria.[1] Few investigators have evaluated discoloration in clinical studies directly using other criteria, or indirectly.[4–6] However, interexaminer agreements are relatively poor when the USPHS criteria are used to rate bulk discoloration, varying between 68% and 78%; the range of agreement is between 54% and 72% for cavosurface marginal discoloration.[3]

The main advantage of using an indirect technique is that permanent records of the restorations enable the calibration and training of evaluators, and allow future examinations with other criteria. There is, therefore, a need to develop standardized indirect techniques for recording and scoring bulk and cavosurface marginal discoloration of restorations. Thus, an assessment was made of the use of color transparencies for scoring bulk and cavosurface marginal discoloration, and the results were compared to those obtained with the direct clinical USPHS evaluation technique.

## Method and materials

One dentist placed 131 restorations in 57 patients between August 1980 and June 1982. The indication for placing the restoration was primary caries or replacement of failed restorations. The average age of the patients was 40 years (range of 9 to 72 years).

The cavity preparations were done according to the principles recommended by Charbeneau.[7] All enamel

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*Table 1* Restorations by type and tooth

| Restoration | Tooth No. 13 | 12 | 11 | 21 | 22 | 23 | 42 | 41 | 31 | 32 | 33 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Concise (n = 28)* | | | | | | |
| Class III | | | 9 | 6 | 1 | 1 | | 2 | 2 | 1 | 2 |
| Class IV | | | 1 | 1 | | | | | | | |
| Class V | 1 | | | 1 | | | | | | | |
| | | | | | *Silar (n = 66)* | | | | | | |
| Class III | 2 | 13 | 13 | 8 | 7 | | 2 | 2 | 2 | 4 | 2 |
| Class IV | | 2 | 2 | | | | | | | | |
| Class V | 1 | | 3 | 1 | | 2 | | | | | |
| | | | | | *Silicap (n = 37)* | | | | | | |
| Class III | | 3 | 9 | 7 | 9 | 4 | | | 1 | | |
| Class V | | 1 | | | | | 1 | 1 | 1 | | |

cavosurface margins were beveled, and a calcium hydroxide base (Dycal, Caulk) was applied to all exposed dentinal surfaces, when indicated. Rubber dam was used consistently. Enamel margins of cavities to be restored by either of the composite resin materials were etched for 60 seconds with the acid solution supplied by the manufacturer (37% orthophosphoric liquid). The clinician followed the manufacturer's recommendation for handling the materials. The composite resins were applied with a syringe, and a plastic matrix strip was used to confine and contour the restorative material. The finishing was done with finishing burs and strips (Sof-Lex, 3M Dental).

The material consisted at baseline of 112 Class III, 6 Class IV, and 13 Class V restorations, located in maxillary and mandibular anterior teeth (Table 1). Each patient received at least one microfilled composite resin restoration (Silar, 3M Dental). If a second restoration was indicated, it was made either from a macrofilled composite resin (Concise, 3M Dental) or a silicate cement (Silicap, Vivadent). In a few patients all three materials were used. The batch numbers of the materials and some characteristics of the composite resins are shown in Table 2. The restorative materials were randomly assigned to the teeth to be restored.

The materials were chosen to represent the latest in tooth-colored material technologies within their respective categories in the late 1970s.[10] Concise and Silicap have not been registered on the NIOM certification lists since 1986, although the materials are still available for sale in Scandinavia. Silar Dark Yellow, Silar Grey, Silar Yellow, and Silar Universal are included on the latest NIOM certification list.[11]

All patients were recalled for polishing and baseline evaluation within 2 weeks. After the polishing, the patients were recalled at 6 months, and then each year. At every recall up to 6 years the restorations were rated by two trained dentists according to the protocol of the USPHS system.[3] After this period, only the failure dates and reasons of replacement of the restorations were recorded. All evaluations, except color match, were done after the field was dried with an air syringe. The color evaluation was done under color-corrected overhead lighting in a wet field without any transillumination. The restorations were also photographed. The photographs were made with a 200-mm Medical Nikor lens (Nikon) at ×1.5 magnification, using 35-mm color film, from both the buccal and lingual sides if required to show the full extent of the restoration. The dentist had been supplied with a copy of the initial photograph to help in the standardization of the subsequent photographs.

In addition to the clinical evaluation, assessments of bulk and cavosurface marginal discoloration were made on color transparencies at ×20 magnification. The discoloration on the photographs was scored according to selected reference sets consisting of three groups. The three groups showed increasing discolora-

*Table 2* Batch numbers of the materials and characteristics of the two composite resins

| | Silicap | Concise | Silar | Source/Reference |
|---|---|---|---|---|
| Batch No. | 121378 1033 | 052279 | 040479 | |
| Matrix | | | | |
| bis-GMA | | 73% | 35% | Ruyter and Sjøvik[8] |
| TEGMA | | 25% | 52% | Ruyter and Sjøvik[8] |
| Filler | | | | |
| Type | | Quartz | $SiO_2$ | Manufacturer |
| Particle size | | 30 μm | 0.04 μm | Manufacturer |
| Weight (% inorganic filler) | | 77% | 51% | Ruyter and Sjøvik[8] |
| Physical properties | | | | |
| Coefficient of thermal expansion | | 35 ppm/C | 51 ppm/C | Manufacturer |
| Surface roughness | | 0.140 | 0.041 | Vanherle et al[9] |
| Elasticity modulus | | 20 MPa | 6 MPa | Manufacturer |


Fig 1 The scoring system for bulk discoloration, evaluated on photographic transparencies at ×20 magnification. Alfa scores have discoloration less than or equal to that shown on the four photographs to the left. Bravo scores have discoloration between the levels shown on the Alfa and Charlie photographs. Charlie scores denote discoloration greater than or equal to that shown on the four right-hand photographs. The upper left photographs show too-light Class IV restorations; the upper right show too-dark Class IV restorations; the lower left show too-light Class III restorations; and the lower right show too-dark Class III restorations.


Fig 2 The scoring system for cavosurface marginal discoloration, evaluated on photographic transparencies at ×20 magnification. Alfa scores have discoloration less than or equal to that shown on the four left-hand photographs. Bravo scores have discoloration between the levels shown on the Alfa and Charlie photographs. Charlie scores denote discoloration greater than or equal to that shown on the four right-hand photographs. The upper left photographs show buccal Class III restorations; the upper right shows lingual Class III restorations; the lower left shows Class IV restorations; and the lower right shows Class V restorations.

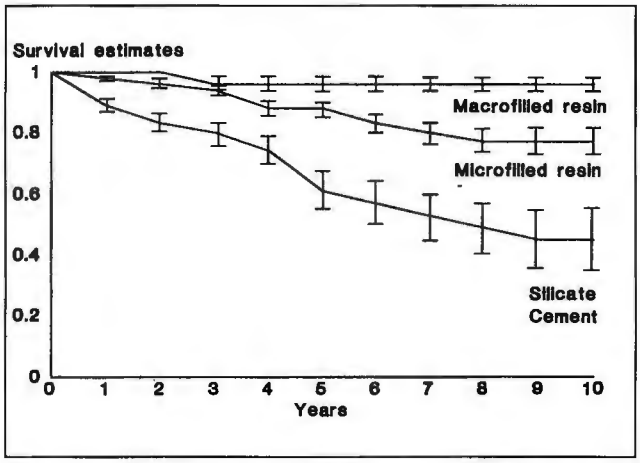


Fig 3 The estimated survival curve over 10 years of the macrofilled (n = 28) and microfilled (n = 66) composite resin restorations and the silicate cement restorations (n = 37). The vertical lines represent 95% confidence intervals.

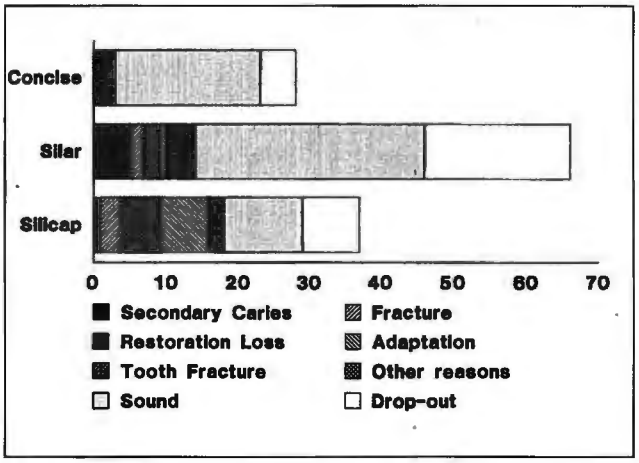


Fig 4 The clinical performance over 10 years of the macrofilled (Concise, n = 28) and microfilled (Silar, n = 66) composite resin restorations and the silicate cement restorations (Silicap, n = 37). The unshaded areas represent restorations lost to follow up because of patient dropout, the lightly shaded areas represent acceptable restorations after 10 years, and the heavily shaded areas represent replaced restorations and the different reasons for replacement.

tion and attempted to represent equal intervals of perceptible difference in the extent of discoloration (Figs 1 and 2). All photographic scorings were made by two dentists after completion of the study. They used USPHS criteria adapted to the photographic assessment. Any differences in the photographic evaluation scores between the two dentists were solved by mutually acceptable agreement to one value.

The estimated survival of the whole observation sample was computed with Kaplan-Meyer survival analyses.

The macrofilled and microfilled composite resin restorations of similar Class, outline, and location in adjacent or contralateral teeth were compared for bulk and cavosurface marginal discoloration, using the Fisher exact test on the USPHS ratings after 6 years in 20 patients ($n = 2 \times 20$).

Kappa statistics were used to assess the agreement between the direct USPHS ratings and the indirect photographic evaluation scores for bulk and cavosurface marginal discoloration.

## Results

After 10 years, 65 restorations remained for observation (50%). The loss of restorations was primarily caused by patient dropout (n = 35), while 26 restorations became unacceptable because of restoration failure. The remaining five restorations were lost to extraction or crowning of the teeth. The estimated survival curves for the three restorative materials over 10 years are shown in Fig 3.

The prevailing replacement reasons were secondary caries, loss of restoration, and poor surface anatomy. However, differences among the three restorative materials were noted (Fig 4).

The clinical ratings according to the USPHS criteria during the first 6 years of the observation period are shown in Table 3. Apparently, unacceptable USPHS ratings did not automatically result in restoration replacements. The lack of consistency between the unacceptable USPHS ratings and replacements was especially apparent for the criteria used to define secondary caries. Table 3 also shows that the microfilled composite resin and the silicate cement restorations had overall poorer USPHS ratings than did the macrofilled composite resin restorations.

Table 4 presents the data for the bulk and cavosurface marginal discoloration of the contralateral microfilled and macrofilled composite resin restorations, while Fig 5 shows representative restorations after 6 years of service. For some patients, both types of com-

*Table 3* Ratings of the restorations according to the USPHS criteria

| | Color match (A-B-C) | Cavosurface discoloration (A-B-C) | Anatomy (A-B-C) | Marginal adaptation (A-B-C-D) | Caries (A-B) |
|---|---|---|---|---|---|
| | | | *Concise* | | |
| Baseline | 23- - | 27- - | 27- - | 27- - - | 27- |
| 6 mo | 22- - | 21- 5- | 25-1- | 24- 2- - | 26- |
| 1 y | 16-2- | 17- 5- | 19-3- | 20- 2- - | 22- |
| 2 y | 15-3- | 19- 2- | 18-3- | 19- 2- - | 21- |
| 3 y | 13-4- | 17- 4- | 18-3- | 20- 1- - | 21- |
| 4 y | 14-3- | 17- 4- | 20-1- | 17- 4- - | 21- |
| 5 y | 13-3- | 18- 2- | 19-1- | 18- 2- - | 20- |
| 6 y | 14-2- | 18- 2- | 18-2- | 17- 3- - | 20- |
| | | | *Silar* | | |
| Baseline | 58- - | 62- 1- | 61-2- | 62- 1- - | 63- |
| 6 mo | 51-1- | 49- 8- | 55-2- | 53- 4- - | 56-1 (*) |
| 1 y | 35-1- | 34- 6-1 (o) | 37-3-1 (o) | 35- 6- - | 38-3 (ooo) |
| 2 y | 35-1- | 32- 9- | 39-2- | 36- 5- - | 39-2 (oo) |
| 3 y | 33-3- | 31-10- | 37-4- | 28-13- - | 38-3 (*oo) |
| 4 y | 21-5- | 24- 7- | 29-2- | 21-10- - | 28-3 (ooo) |
| 5 y | 18-7- | 24- 6- | 26-4- | 26- 3-0-1 (*) | 27-3 (ooo) |
| 6 y | 11-8- | 22- 1-1 (o) | 16-7-1 (*) | 18- 4-1-1 (*o) | 22-2 (*o) |
| | | | *Silicap* | | |
| Baseline | 33- | 36- - | 36- - | 36- - - | 36- |
| 6 mo | 22-5 | 24- 4-2 (oo) | 27-2-1 (*) | 18- 8-0-4 (***o) | 30- |
| 1 y | 20-4 | 22- 4-1 (o) | 23-4- | 24- 3- - | 27- |
| 2 y | 18-5 | 21- 5- | 17-9- | 18- 8- - | 25-1 (*) |
| 3 y | 17-5 | 18- 6-1 (o) | 16-6-3 (***) | 15- 7-1-2 (***) | 25- |
| 4 y | 11-3 | 13- 4- | 10-6-1 (*) | 11- 5-0-1 (*) | 17- |
| 5 y | 9-2 | 7- 6-1 (o) | 9-5- | 6- 8- - | 14- |
| 6 y | 8-2 | 10- 2-1 (o) | 9-4- | 6- 7- - | 13- |

Color match, cavosurface discoloration, anatomy: A and B = acceptable; C = unacceptable.
Marginal adaptation: A and B = acceptable; C and D = unacceptable.
Caries: A = acceptable; B = unacceptable.
o = unacceptable USPHS rating; restoration not replaced.
* unacceptable USPHS rating; restoration replaced.

posite resin discolored markedly compared to those in other patients. In some patients, discoloration was only observed in one of the composite resin materials (Fig 5).

The USPHS ratings for bulk and cavosurface marginal discoloration did not differ between the two composite resin materials, according to the Fisher exact test. The statistical tests indicated $P = .12$ for bulk discoloration and $P = .19$ for cavosurface marginal discoloration.

Comparisons of the direct USPHS ratings with the indirect photographic scores are shown in Table 5. Overall, the photographic scores were usually the same or poorer than the direct USPHS ratings, except for two restorations in which the direct USPHS ratings in-

*Table 4* USPHS ratings of bulk and cavosurface margin discoloration of paired microfilled and macrofilled composite resin restorations after 6 years of clinical service

| | | Bulk discoloration | | | | Cavosurface marginal discoloration | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Macrofilled | | | | Macrofilled | | | |
| | | Alfa | Bravo | Charlie | Total | Alfa | Bravo | Charlie | Total |
| Microfilled | Alfa | 9 | 0 | 0 | 9 | 17 | 1 | 0 | 18 |
| | Bravo | 5 | 2 | 0 | 7 | 0 | 1 | 0 | 1 |
| | Charlie | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Total | 14 | 2 | 0 | 16 | 18 | 2 | 0 | 20 |

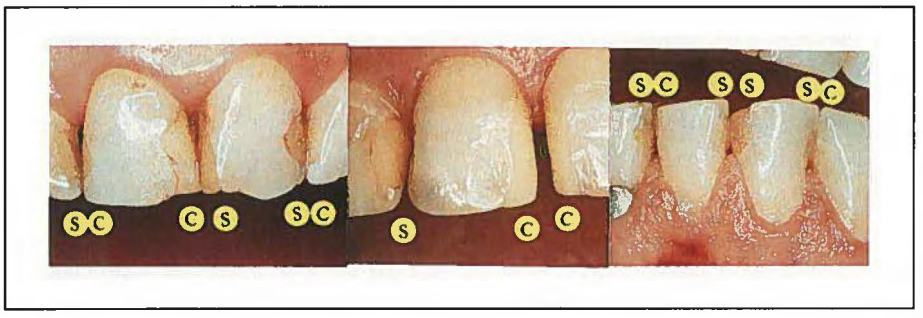


Fig 5 Representative *(C)* macrofilled and *(S)* microfilled composite resin restorations after 6 years. The left frame shows only slight, but distinguishable, differences in discoloration of the Class III microfilled restoration and the two Class IV macrofilled restorations. The center and right frames show more obvious differences in discoloration.

*Table 5* Agreements of the direct USPHS ratings and the indirect scores in evaluating bulk and cavosurface marginal discoloration

| | | USPHS direct ratings | | | |
|---|---|---|---|---|---|
| | | Alfa | Bravo | Charlie | Total |
| | Color match* | | | | |
| Photographic scores | Alfa | 22 | 0 | 0 | 22 |
| | Bravo | 11 | 3 | 0 | 14 |
| | Charlie | 6 | 4 | 0 | 10 |
| | Total | 39 | 7 | 0 | 46 |
| | Cavosurface marginal discoloration† | | | | |
| Photographic scores | Alfa | 28 | 0 | 0 | 28 |
| | Bravo | 11 | 8 | 2 | 21 |
| | Charlie | 3 | 2 | 1 | 6 |
| | Total | 42 | 10 | 3 | 55 |

* Agreement on scoring .54; $\kappa = .17$
† Agreement on scoring .68; $\kappa = .40$

dicated more discoloration than was shown on the photographs.

## Discussion

The results of the study confirmed the well-known fact that composite resins have superior general performance but higher secondary caries incidence than do silicate cements.[12,13]

The dentist did not always replace the restoration when one or more aspects were rated unacceptable by the criteria of USPHS system. This finding indicates that the dentist practiced a treatment philosophy that for several years has been taught in Scandinavian dental schools. This treatment philosophy advocates observation and preventive measures rather than immediate operative intervention when color and surface discrepancies are observed. Recently, this practice has also been recommended by a consensus symposium on the placement and replacement of restorations.[14]

The advantages of microfilled composite resins over conventional types is their ability to provide smooth

surfaces and better translucency. However, the macrofilled resin showed better survival than did the microfilled composite resin. In spite of increased surface roughness and plaque retention, no secondary caries was observed among the macrofilled composite resin restorations. In comparison, five microfilled composite resin restorations were replaced because of secondary caries. The increased proportion of organic matrix in microfilled composite resins results in a lower modulus of elasticity and a higher coefficient of thermal expansion. These physical properties have been related to increased marginal leakage and secondary caries,[15] although no clinical studies have confirmed such a relationship. The present data are in agreement with the hypothesis, but the low number of restorations with secondary caries and the unequal placement of microfilled and macrofilled composite resin restorations preclude any definite conclusions. On the other hand, the results indicated that it is probable that other material factors besides the surface roughness are related to increased risk of secondary caries along composite resin restorations. This is in agreement with results of a previous report on a 6-year longitudinal study of seven anterior composite resins.[16]

Several clinical studies have reported on the performance of Concise and/or Silar after 3 years,[17-19] 5 years,[20] 6 years[16] and 16 years.[21] The present results from a general dental practice are in many respects different from other clinical studies, possibly because most studies are done on selected patients or by dentists working without time constraints. Only studies with more than 5 years of observation report any secondary caries.[16,20,21] The poorer clinical USPHS ratings for anatomic form among the microfilled composite resin restorations indicate that they had less resistance to surface material loss than did the macrofilled composite resin restorations, in contrast to other clinical data.[17] Finally, the present long-term data for the Concise restorations are significantly better than those reported by Smales,[21]; those restorations were placed in a dental school. Van Dijken[16] reported that 30% of the restorations made from Silar show unacceptable discoloration after 4 years, and 40% after 6 years. Davis and Mayhew[17] reported that Silar restorations tend to be slightly more opaque and lighter than the surrounding tooth structure. Other investigators have reported marked discoloration of Silar restorations. Timmons et al[18] reported that the conventional = type composite resins show better color stability than the microfilled-type composite resins; their findings differ from the present results. Dogon et al[19] replaced 47% of 583 Silar restorations after 3 years; of these, 93% were replaced because of bulk discoloration. Crumpler et al[20] concluded that microfilled composite resins display poorer color match than the conventional composite resins, and that a decline in color resistance occurs mainly after 2 years. Lambrechts et al[22] have also suggested that restorations made from Silar become unacceptable after 4 to 5 years because of yellow-brown bulk discolorations.

Previous studies have shown that the use of enlarged color transparencies is helpful for assessing several clinical characteristics of composite resin restorations.[4-6] The disadvantage of using color transparencies is that interproximal tooth regions cannot be examined. Additionally, restoration margins placed subgingivally cannot be assessed, although the presence of gingivitis can be scored semiquantitatively. Further disadvantages of the indirect technique are that fractures along the cavosurface margins and the surface texture are difficult to detect,[4,23] and that two photographs are needed to evaluate the full extent of the cavosurface margins. On the other hand, the main advantage of photographs over direct clinical evaluations is the permanent recording of the restoration status. Furthermore, the procedure for recording the restorations is repeatable and enables an objective recording of the color differences.

The poor correlation between the USPHS ratings and the photographic scores for bulk and cavosurface marginal discoloration indicated that the clinical evaluation may be the least sensitive of the two techniques. However, the reflectance spectra from tooth-colored materials and hard tissues differ, and the differences depend on the wavelength of the incident light.[24] Furthermore, there are differences in microfilled and macrofilled composite resins, because of the different light-scattering properties of small and large filler particles[25] (see Table 2). Finally, in translucent materials, the reflectance spectra are influenced by the specimen thickness[26] and the surface morphology.[27] Thus, the discrepancy of the direct and indirect evaluations may signify that the reflectance spectra of the tooth and the restoration recorded on a photograph under a specific illuminant cannot normally be created in vivo.

Composite resin discoloration may arise from three causes: surface staining, changes in the opacity resulting from alteration of the interface between the resin and filler, or intrinsic discoloration of the resin matrix by thermal or photochemical means.[28] The relative importance of the three mechanisms on bulk and on cavosurface marginal discoloration will vary for different

patients, as observed in the present study (see Fig 5). Recent findings have shown that two types of intrinsic discoloration of composite resin restorations may be present.[29] One mechanism is dependent on chemical alterations of the different material components, ie, the chemical activators, initiators, inhibitors, and monomers. Traditionally, the bulk discoloration in chemically activated composite resins has been related to oxidation of the tertiary amines used in the initiator/accelerator catalytic system,[30] which was the same for the two composite resins in the present study. The main differences between the two composite resin materials were the significantly higher organic matrix and the smaller filler particles in the microfilled composite resin. An oxidation of residual unreacted C = C in the organic matrix produces colored peroxide compounds and a yellowing of the material.[31] Thus, the clinical advantage of obtaining a smoother surface is compromised by the increased content of organic matrix that may decrease the color stability.[17] The other bulk discoloration mechanism is penetration of extrinsic colorants.[29] To what extent this discoloration mechanism occurred in the present study is uncertain. Finally, the appearance of surface discoloration is influenced by the surface roughness.[27] Dentists commonly polish the tooth surfaces with pumice at yearly recalls. Although the short-term effect of this polishing may be evident, no studies have shown yearly polishing to have a beneficial effect on the long-term resistance against bulk discoloration.

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