

Retrospective clinical study of 656 cast gold inlays/onlays in posterior teeth, in a 5 to 44-year period: Analysis of results

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DOI: 10.22592/ode2018n31a6

Abstract

Objective. 1) To assess the clinical performance of 656 cast gold inlay/onlays in a 44-year period; 2) To analyze their indications and distribution regarding the evolution of scientific evidence. **Materials and Methods.** A total of 656 cast gold inlays/onlays had been placed in 100 patients. Out of 2552 registered patients, 210 fulfilled the inclusion criteria. The statistical representative sample was 136 patients; 140 were randomly selected and 138 were the patients studied. Twelve variables were analyzed. Data processing was done using Epidat 3.1 and SPSS software 13.0. **Results.** At the clinical examination, 536 (81.7%) were still in function and 120 (18.3%) had failed. According to Kaplan-Meier's method, the estimated mean survival for the whole sample was 77.4% at 39 years and 10 months. **Conclusions.** Knowledge updating is an ethical responsibility of professionals, which will allow them to introduce conceptual and clinical changes that consider new scientific evidence.

Keywords: inlays/onlays, molar, premolar, dental bonding restorations, scientific evidence-based, minimally invasive dentistry.

Disclosure

The authors declare no conflicts of interest related with this study.

Acknowledgements

To Lic. Mr. Eduardo Cuitiño, for his responsible and efficient statistical analysis of the data collected by the authors.

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Introduction

Restorations in posterior teeth, mainly molars, withstand the greatest occlusal forces. Moreover, 40% greater forces could be observed in patients with bruxism, increasing their risk of failure⁽¹⁾. Additionally, restorations covering more surfaces have had greater risk of failure⁽²⁾. For over 100 years, cast gold restorations have been widely used, mainly in posterior teeth. Several clinical studies show excellent quality, longevity and functional performance⁽³⁻⁶⁾.

Since the beginning of the nineties there has been a permanent scientific and technological development of adhesive ceramic materials for posterior inlays/onlays. Clinical studies and systematic reviews have shown very good results⁽⁷⁻¹²⁾. Moreover, improving biomechanical and optical properties in direct light-activated composite resins⁽¹³⁻¹⁸⁾, as well as in the adhesive systems⁽¹⁹⁻²²⁾ has increased their use⁽²³⁻²⁴⁾, showing high long-term clinical success, performing extended and large restorations in posterior teeth⁽²⁵⁻³²⁾. This scientific evidence has provided the basis for using these materials as substitutes of cast gold restorations.

At the same time, cultural, sociological and psychological factors related to self-esteem⁽³³⁾ and new aesthetic parameters⁽³⁴⁻³⁶⁾ have increased patients' demand for tooth-colored restorations. All the above can change concepts and clinical procedures, leading to a reduction in the indication and placement of cast gold inlays/onlays. These changes were observed in productivity studies conducted by the operator in his private office in over 25 years. In fact, between 1995 and 2000 there was a 19.8% decrease in the use of gold inlays/onlays (GIOs) (Fig. 1), an increase of 107.6% in the placement of bonded ceramic inlays/onlays (BCIOs) (Fig. 2) as well as a 44.7% increase in posterior direct light-activated composite resins (PCRs) (Fig. 3).

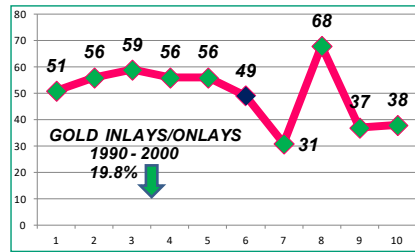


Fig. 1. The chart shows a decrease in the use of GIOs since 1995 (blue dot).

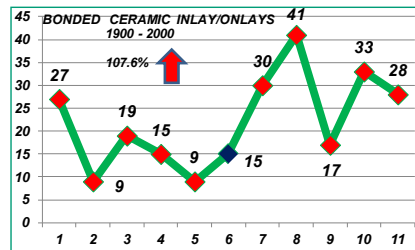


Fig. 2. The chart shows an increase in the use of BCIOs since 1995 (blue dot).

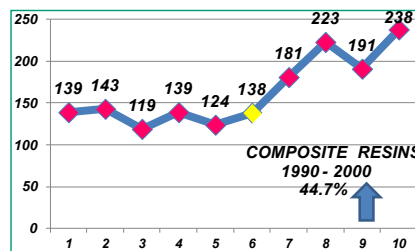


Fig. 3. The chart shows an increase in the use of PCRs since 1995 (yellow dot).

The right selection and the proper handling of the new materials are possible if the professional's knowledge is scientific and evidence-based. In fact, it is an ethical responsibility.

Therefore the aims of this article were: 1) to assess the clinical performance of 656 cast gold inlay/onlays in a 44-year period, and 2) to analyze their indications and distribution in relation to the evolution of scientific evidence.

Materials y Methods

This work was approved by the Ethical Board of the School of Dentistry, Universidad de la República.

From April 2013, a retrospective clinical longitudinal study on six restorative procedures, performed by the first author in his private practice, has been conducted covering a 44-year period. Four articles have been published^(12,32,37,38). This paper presents the results of a new study in the series.

To be included in the study, the patients must have been treated and evaluated in the first author's office for at least seven years and be still in the practice by 2013, with complete dental arches (healthy or restored teeth). The patients with removable dental prosthesis, disabilities, that had moved or passed away were excluded. The GIOs must have been in function for at least five years to be included in the study. The failure criteria were: loosening, removal of the restoration or tooth lost.

Out of 2552 registered patients, 210 fulfilled the inclusion criteria and 136 patients were a statistically representative sample (at the lowest range, a 95% CI for a proportion, with a length of $\pm 5\%$). Of these 210 patients, 140 were selected at random by a dental assistant, who was blinded to the aim of the selection. They were invited to participate in clinical examinations between November 2013 and April 2014: 138 agreed to participate.

Considering the period of the clinical examination (11/2013 - 04/2014), the inclusion criteria for the GIO (> 5 years in function), and the second aim of this research, the restorations to be analyzed were divided into two groups, according to the date of placement: A - between April 1969 and April 1991, and B - between April 1991 and October 2008.

According to the Glossary of Prosthodontics Terms⁽³⁹⁾, the meaning of inlay and onlay terms were slightly modified in this work for practical

reasons: "inlay" is when the GIO covers partially the occlusal surface, including one or more cusps; "onlay" when the GIO covers the whole occlusal surface.

Patient-based data were collected from the clinical personal charts and clinical examinations for each patient, and then recorded on specially designed sheet forms.

All restorations were made by the first author. The co-authors participated as independent evaluators. The calibration between the authors was undertaken previously on 120 restorative procedures from outside the sample. Cohen's Kappa Coefficient on the quality of restorations ranged from 0.78 to 1 (excellent according to Fleiss's guidelines).

To establish the quality of the restorations, marginal adaptation (MA), marginal discoloration (MD), and occlusal surfaces (S) were the variables evaluated according to Ryge's criteria⁽⁴⁰⁾; however, these variables were modified by the authors (Table 1).

As was previously published⁽³²⁾, four success criteria (SC) were established on the quality of the GIOs:

- **Excellent** (Ex): When MA, MD, and S were rated "Alpha" in the same GIO. This group represents the best quality restorations.
- **Good** (G): When at least one variable (MA, MD, S) was rated "Bravo" in the same GIO. This group was considered of satisfactory clinical acceptance.
- **Functional survival** (FS): When at least one variable (MA, MD, S) was rated "Charlie" in the same GIO. These restorations must be controlled, repaired or retreated.
- **Clinically successful** (CS): To establish clinical success, the GIOs in function rated "Excellent" and "Good", were considered jointly.

MARGINAL ADAPTATION
ALPHA: No lack of continuity along the margin observed with the explorer.
BRAVO: Evidence of a crevice along the margin, but the explorer cannot penetrate.
CHARLIE: Evidence of a crevice along the margin, which an explorer can penetrate. Requires control, repair or retreatment.
MARGINAL DISCOLORATION
ALPHA: No pigmentation anywhere on the margin.
BRAVO: Pigmentation present but does not penetrate the margin toward the pulp.
CHARLIE: Severe pigmentation. The restoration must be removed.
SURFACE
ALPHA: The surface of the restoration is unaltered.
BRAVO: The surface of the restoration shows wear and must be controlled.
CHARLIE: The surface of the restoration shows perforations, fractures or significant tear. It must be polished, repaired or retreated.

Table 1. Ryge's criteria⁽⁴⁰⁾, modified by the authors, to establish the quality of GIOs.

Patients signed an informed consent before the clinical examination. The clinical exams were blinded among the authors and performed with a mirror and a sharp explorer (Maillefer 6: Maillefer, Ballalgués, Switzerland). In cases of disagreement regarding the assessment of the quality of the restorations, the lowest rating was recorded.

The operator always conducted a clinical and functional study of the Stomatognathic System (SE). These data, as well as the clinical procedures performed, the materials applied and the patient's biological response were thoroughly recorded.

Since its availability in the market, a panoramic radiograph was always indicated. When restorations, carious lesions and/or periodontal disease were present, standard X-rays were requested.

All the patients were enrolled in a comprehensive prevention plan and advised to undergo periodical maintenance therapy. Since the late eighties, if caries disease was present, biochemical and microbiological saliva tests were indi-

cated and a dietary form filled. The aim was to establish the individual caries risk and to implement the specific etiological treatments⁽⁴¹⁻⁴⁴⁾. Furthermore, non-cavitated carious lesions were treated with topical fluorides.

Tooth preparation is considered by the operator as the most important factor in the clinical success of the restorative treatment. It must be based on a conservative approach, according to the extension of the carious lesion, remnant tooth structure, location of occlusal contacts, crown height, occlusal plane, habits of the patient, biomechanical properties of the restorative materials and aesthetic considerations. In deep cavities, a thin layer of self-cured calcium hydroxide was applied in the pulpal wall and covered with glass-ionomer cement.

The variables analyzed were age, gender, type of restoration, number, location, extension, quality and longevity of the restorations, type of cement, secondary caries, parafunctional habits and maintenance therapy.

Data processing was performed using Epidat software (Conselleria de Sanidade de la Xunta

de Galicia, Santiago de Compostela, Spain) v 3.1 developed by the Consellería de Sanidade de la Xunta de Galicia with the support of PAHO-WHO and SPSS software v13.0 (SPSS Inc., Chicago, IL). In all cases, the variables considered corresponded to an identically distributed independent random variable that was generated from a probability sample. A result was considered statistically relevant when, upon the rejection of a null hypothesis, the probability of error was less than 5%. Statistical significance was set at $P < 0.05$. When analyzing the complete and censored values, the mean and median values were used to describe the central tendency. If the number of complete values was too small, a Kaplan-Meier's curve could not be used. Therefore, a Fisher's exact test, Chi-square test, Kruskal-Wallis test, and Mann-Whitney non-parametric test could be indicated to analyze significant differences.

Results

Six hundred and fifty-six GIOs had been placed in 100 patients. The observed mean age was 63 years and 9 months for both sexes. The observed mean time of attendance per patient was 30 years and 5 months.

Carious lesions [557], endodontic treatment [85], functional requirements [7], trauma [4] and periodontal disease [3] were the reasons to perform the GIOs.

The number of GIOs per patient varied from 1 to 20. The average was 6.56 GIOs per patient: 6.22 in women and 7.07 in men. No statistical significant difference was found regarding sex (Mann-Whitney Test, $p = 0.92$).

GIOs in function and failed

At clinical examination, 536 GIOs (81.7%) were in function. The observed mean survival (OMS) was 27 years and 1 month. According to the date of placement, 343 were in group A- and 193 in Group B-.

One hundred and twenty GIOs failed (18.3%), 61 in 16 men and 59 in 17 women; 119 in

Group A- and 1 in Group B-. The OMS for failures was 18 years and 4 months. No statistically significant differences between the IOOs in function (Student T Test, $p = 0.65$), nor in the failures (Student T Test, $p = 0.99$) were observed in both sexes.

The annual failure rate was 0.08%. The estimated mean survival time (EMS), according to the Kaplan-Meier's method, was 85% at 25 years and 77.4% at 39 years and 10 months (Fig.4).

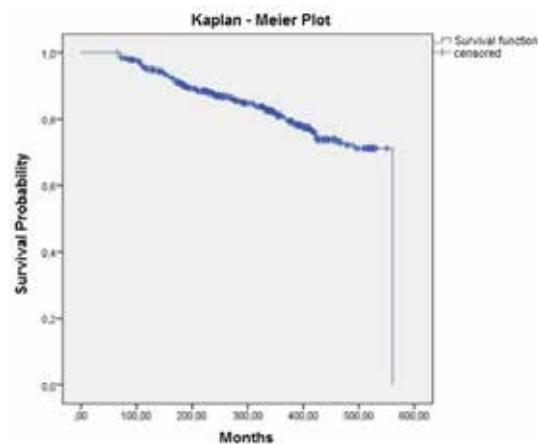


Fig. 4. Overall estimated mean survival according to Kaplan-Meier's curves.

Considering **location**, 331 GIOs in function were in molars and 205 in premolars. There was a statistically significant difference in the number of GIOs in function, restoring molars and premolars, between the two groups (OR = 0.42, $p < 0.001$) (Fig. 5).

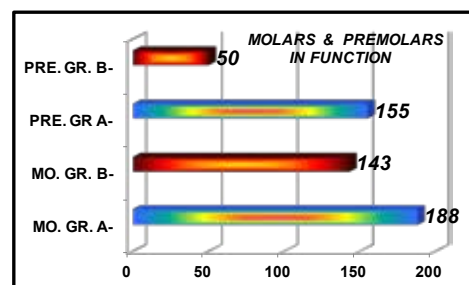


Fig. 5. Distribution and number of GIOs in function in molars and premolars in both groups (MO. = molars; PRE. = premolars; GR. = group).

Out of 120 failures, 89 were in molars and 31 in premolars. Premolar survival was significantly higher (Log Rank Test, $p < 0.0001$). According to Kaplan-Meier's method, EMS was 479.8 months (39 years and 11 months) for premolars and 437.4 months (35 years and 5 months) for molars (Fig. 6).

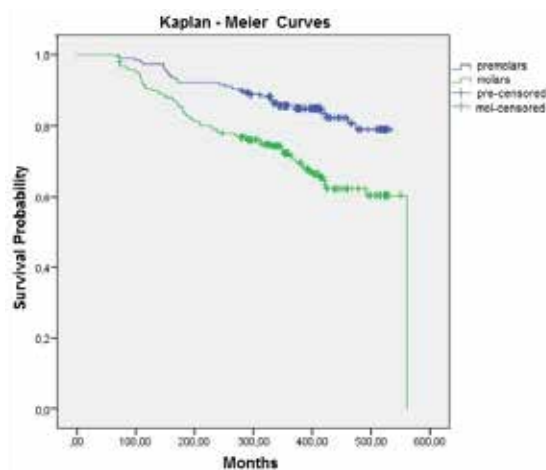


Fig. 6. Survival Kaplan – Meier's curves between premolars and molars.

Regarding **type of restoration**, 424 GIOs were onlays and 112 inlays. A statistically significant difference was observed in the number of onlays and inlays in function between the two groups (OR = 13.9, $p < 0.0001$). Thirty-eight onlays and 82 inlays failed. Onlays presented a higher statistical survival rate (Log Rank Test, $p < 0.0001$). The Kaplan-Meier's curves showed an EMS of 498.4 months (41 years and 6 months) for onlays and 402.2 months (33 years and 6 months) for inlays (Fig.7).

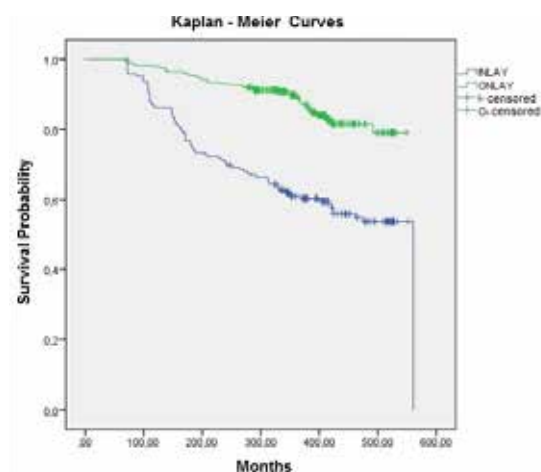


Fig. 7. Survival Kaplan-Meier's curves between onlays and inlays

Considering **extension**, 95% of the all GIOs, covered 3 surfaces: 507 in function and 116 failures; 20 covered 2 surfaces (4 failures) and 13 more than 3 surfaces.

Regarding **pulp state** at the moment of placement, 86.6% of the GIOs, restored vital teeth (VT): 457 in function and 111 failed. Out of 88 (13.4%) endodontically treated teeth (ETT), 79 remained in function and 9 restored with casts posts failed, but only one was fractured. Furthermore, 9 GIOs in VT had to be removed for endodontic treatment (1.4%).

Three GIOs were fixed with resin cement (Panavia, Kuraray, Japan) and 653 with zinc phosphate cement. One GIO fixed with zinc phosphate cement loosened after 32 years in function.

Secondary caries was the major reason for failures (14.9%): 89 in occlusal surfaces and 9 in gingival location. Of the 120 failures, 15 teeth (14 in group A and 1 in group B) were lost.

Table 2 summarizes the information on failures presented above.

In addition, 105 teeth in group A-, that had lost their GIOs could be retreated: 90 with new GIOs, that were included in this study, and 15 with other restorative procedures. Out of 90 GIOs (89 onlays and 1 inlay), 39 were retreated before April 1991, remaining in group A. Fifty

one performed after April 1991 were included in group B- .

PERIOD	O/C	G/C	End.	Perio.	Fra.	Loos.	R.R.	TOTAL
< 10 y	24	3	2	1	1	0	1	32
10 - 20 y	34	1	3	4	0	0	1	43
20 - 30 y	21	0	4	1	0	0	0	26
30 - 40 y	10	3	0	3	0	1	0	17
> 40 y	0	2	0	0	0	0	0	2
TOTAL	89	9	9	9	1	1	2	120
%	74.2	7.5	7.5	7.5	0.8	0.8	1.7	100

Table 2. Failures of GIOs: causes, number, distribution in decades and percentages (O/C = occlusal caries; G/C = gingival caries; End.= endodontic treatment; Perio.= periodontal disease; Fra.= root fracture; Loos. = loosened; R.R.= root resorption; y = year).

Meanwhile, group B- included 194 GIOs placed after April 1991 (193 in function, 1 failure). The distribution of the 193 GIOs in function was: 48 in 22 patients that had not been in group A-; the above mentioned 51 GIOs retreated, and the 94 new GIOs placed in 62 patients in group A- (Table 3).

PERÍOD	Gr. B	Gr. A/B	RETR.	TOTAL
04/91 - 04/95	9	35	19	63
04/95 - 04/99	15	29	18	62
04/99 - 04/04	12	18	8	38
04/04 - 10/08	12	12	6	30
TOTAL	48	94	51	193

Table 3 . Distribution of GIOs in function in group B-, placed after April 1991, according to the period of placement and their origin (Gr. B- = GIOs installed in new patients; Gr. A/B = new GIOs placed in patients of group A-; RETR. = GIOs retreated in patients of group A-).

Success criteria

According to Ryge's criteria⁽⁴⁰⁾ modified by the authors, the results on the quality of the variables analyzed are presented in Table 4. Considering these results, and the previous established

criteria⁽³²⁾, the CS of the GIOs in function was 93.6%. The CS for the whole sample was 76.1%.

	MARGINAL ADAPTATION	MARGINAL DISCOLORATION	OCCLUSAL SURFACE
ALPHA	390	533	465
BRAVO	129	2	50
CHARLIE	17	1	21

Table 4. Number, distribution and quality of the variables analyzed, according to Ryge's criteria⁽⁴⁰⁾ modified by the authors.

Three GIOs in Figure 8 were qualified Ex, and 2 in Figure 9 were qualified B. The GIOs repaired in Figure 10 were qualified as FS.



Fig. 8. GIOs qualified Excellent (a= year, m = months).



Fig. 9. GIOs in premolars (44 years) qualified Bravo (a = year, m = months).

Occlusal function and maintenance.

Twenty-four patients (24%) had had history of parafunction, and 33 (33%) were using stabilization occlusal splints due to bruxism. Thir-

ty-seven patients (37%), 21 women and 16 men, attended at least once a year for maintenance therapy.

Repairs

Meanwhile, in 21 patients, 27 repairs were performed (23 in occlusal and 4 in gingival areas). The materials applied were Direct Light-activated Composite Resin [20], Glass-Ionomer [1] and Amalgam [6]. These GIOs were considered in function and qualified as functional survival. The OMS of the repairs was 12 years and 8 months (range: 3 years to 22 years and 9 months). Two GIOs repaired are shown in Figure 10.



Fig. 10. Repairs with direct light-activated composite resin, in buccal margins of 46 (19 y) and 45 (8y). Both GIOs have been in function for 44 years (y = year).

Discussion

The high percentage of GIOs in function (81.7%) and their EMS were in line with other clinical studies^(3,4,6). Regarding statistical data previously presented in this paper, the variables age and gender did not influence the results. Secondary caries were 81.7% of the all failures, higher than in other studies: 33.7%⁽³⁾ and 40%⁽⁴⁾.

Occlusal carious lesions could be related to biomechanical factors associated with bruxism (marginal and/or surface wear of GIO, cement dissolution), biological factor (bacterial microfiltration) and the lack of periodic maintenance control. Besides, the operator, according

to the minimal invasive criteria, preferred to repair before retreating. This agrees with Fisher and Morgan WW⁽⁴⁵⁾. The fact that 63% of the patients did not attend at least once a year for maintenance therapy could be considered a biological and biomechanical risk factor for failure. Furthermore, parafunction might be a biomechanical risk factor of failure.

Only one GIO loosened (0.15%). This result was very low compared to other clinical studies: 32.7%⁽³⁾ and 31%⁽⁴⁾. This could be due to the design of the tooth preparation, the quality of the restoration and a thorough fixation protocol by the operator.

The higher survival of premolars is in line with other studies^(1,2). Meanwhile, the higher survival of onlays could be explained because onlays transmit mainly compressive forces, giving better protection to the remnant tooth structure^(46,47). Besides, due to the extension, their margins could be less affected by the greater forces exerted in patients with bruxism. In addition, Studer et al.⁽⁴⁾ did not find differences between inlays and onlays. The CS of the GIOs in function was 93.6%, in line with Donovan and Chee⁽⁵⁾ and Donovan T et al.⁽⁶⁾. The development above supports the first objective of this work.

The second aim of this study was to analyze the indication and distribution of GIOs, related to the new scientific evidence. Therefore, both groups must be compared to analyze the constitution of Group B- and to assess the possible coexistence of restorations as substitutes of the GIOs.

In fact, the number of GIOs in function in Group B- (193) was 43.7% less than in Group A-. These patients had been using GIOs for a long time, they knew their results and did not refuse to use gold restorations. Nevertheless, when analyzing Table 3, 32.1% of GIOs were placed in the "transitional period" (1995-1999), 19.7% and 15.6% in the two following periods, respectively. This gradual and constant reduction in the use of GIOs might be due to

alternative restorative procedures proposed by the operator.

Using the same global sample, similar inclusion and exclusion criteria than in this work, and relative similar period of placement than restorations in Group B-, in two articles published by the authors^(12,32) the following was studied:

- 93 IOCA's in 47 patients, placed between 10/1995 - 10/2008 and assessed in a 5 to 18 - year period. Eighty-seven onlays (93.5%) remained in function⁽¹²⁾.

- 105 RCDP's in 61 patients were installed between 10/1993 - 10/2008 and assessed in a 5 to 20-year period; 103 (98%) were in function and 41% were large or extended restorations⁽³²⁾.

Therefore, in the 04/1991 - 10/2008 period, in the same global sample, 50.4% of the partial posterior restorations performed were GIOs and 49.6% RCDP's or IOCA's. Meanwhile, comparing the two groups, in Group B- we observed a reduction of 94.3% and 67.7% in the number of inlays and premolars restored with GIOs, respectively. This could be due to the application of more conservative, aesthetic and efficient restorative materials such as RCDP's.

Besides, the reduction of onlays (21.1%) in Group B-, might be linked to greater use of IOCA's. Whereas in Group B-, only one GIO failed due to periodontal problems. This result could be due to the scientific and clinical changes related to the new preventive actions taken by the operator⁽⁴¹⁻⁴⁴⁾.

Considering all the above, besides the very good clinical results, this work also showed a close connection between the clinical and conceptual changes applied by the operator and the updated scientific evidence.

Only one operator can reduce bias in the analytical comparison, but might improve the clinical success⁽⁴⁸⁾. The results could not be reproducible, but the operator believes this could be a relative limitation⁽⁴⁹⁾.

Conclusions

In this study, a high clinical performance of GIOs was observed. However, as there are more aesthetic restorative materials, with good longevity and requiring simpler and less invasive teeth preparations, GIOs are less indicated by dentists and less accepted by patients.

Updated knowledge is an ethical responsibility of the professional. It will allow dentists to introduce the clinical and conceptual changes, taking into consideration the new scientific evidence, as was observed in this paper.

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Received on: 06.02.2018 – Accepted on: 13.04.2018