Clinical outcomes of minimally invasive ceramic restorations executed by dentists with different levels of experience. Blind and prospective clinical study

Eduardo Passos Rocha a,*, Rodolfo Bruniera Anchieta a,b, Regis Alexandre da Cunha Melo a, Paulo Henrique dos Santos a, Wirley Gonçalves Assunção a, Fernando Isquierdo de Souza a, Ana Paula Martini a

a Unesp – Univ Estadual Paulista, Department of Dental Materials and Prosthodontics, Araçatuba Dental School, Araçatuba, SP, Brazil
b Centro Universitário do Norte Paulista, UNORP, Unipos, São José do Rio Preto, São Paulo, Brazil

Abstract

Purpose: To evaluate the clinical outcomes of minimally invasive ceramic restorations executed by dentists with different levels of experience.

Methods: Sixteen professionals were divided into 4 groups according to their experience levels. These included G1: up to 2 years since graduation, G2: 2-5 years, G3: 5-10 years, and G4: more than 10 years. All professionals were trained to follow the same standardized clinical protocol, but were unaware of the research objectives. A single evaluator followed the clinical treatments and recorded the complications and errors that occurred during the execution of the protocol. Ninety-one full crowns, 137 veneers, and 46 no-preparation veneers were prepared from lithium disilicate. Follow-ups were performed immediately and at 30, 180, and 360 days after the cementation and the evaluation based on the modified United States Public Health Service criteria. Ceramic chipping/fracture and debonding were considered failures. Fractures were replicated and submitted to fractographic analysis.

Results: The highest number of failures were found in G1 followed by G3 and the lowest number of failures were found in G2. The level of success was 94% after 360 days. The fractographic analysis demonstrated the external surface of restorations as the critical area and suggested that failures might occur due to noncompliance with the clinical protocol. There was no correlation between professional experience and number of failures or patient satisfaction.

Conclusions: Professional experience was not a decisive for patient satisfaction and success of minimally invasive ceramic restorations, and noncompliance with the clinical protocol was associated with early ceramic restoration failures.

Keywords: Dental ceramics, Veneers, Clinical study, All-ceramic, Minimally invasive treatment

1. Introduction

Many studies have reported clinical success of ceramic restorations [9-13]. Beier et al. [1] reported up to 93.5% and 82.93% of success for laminate veneers after 10 and 20 years, respectively [2]. Another study reported up to 98.8% of success for similar restorations after 6 years of follow-up [3] and about 98% after 21 years of follow-up [4].

The new-generation of all-ceramic restorations sensible to hydrofluoric acid that relies a high bond strength to tooth structure have allowed esthetic and functional recovery based on maximum preservation of tooth structure [5,6]. Higher success levels are also related with these factors [7]. The survival rate of restorations allow a high bond strength between the ceramics that can be etched with hydrofluoric acid and the tooth structure. This enhance the use of conservative restorations such as veneers with minimal tooth reduction, since the ceramic acquire a high fracture strength after adhesive cementation [8-10]. Furthermore, the presence of enamel plays an important role for higher bond strength and fracture strength [11,12]. Thus, minimally invasive treatments such as the so-called no-preparation veneers and full veneers in anterior and posterior teeth are gaining popularity [13,14].

However, though the reliable bonding capacity of ceramic restorations with tooth substrate, especially enamel, has been achieved to a great extent, majority of the available clinical data has reported results from randomized clinical trials executed by a single or a few highly experienced operators [7,15,16]. Usually, the high level of expertise on the subject of the research is used for better evaluation of the properties of the materials. The parameters for their clinical use are reported without the variables based on the competence of the operators [17].
It is believed that well-defined clinical protocols and well-executed treatment plans reach clinical success, even in a clinical routine with operators showing different levels of expertise or experience. Thus, clinical findings obtained from blind studies conducted by dentists with different levels of experience might show results about the clinical behavior of materials that closely reflect the material behavior in private offices around the world. Such findings might also describe if failures are material-dependent, operator-dependent, or both.

There is a lack of blind clinical studies regarding these aspects, especially those considering the importance of operator as a decisive aspect in the survival rates and the success of ceramic restorations. The objective of the present prospective clinical study was to evaluate the clinical behavior of anterior and posterior ceramic restorations prepared using the minimally invasive approach and executed by dentists with different levels of experience. The following hypotheses were tested: 1) There would be no association between restoration failures and dentists’ experience, 2) The fulfillment of clinical protocol would not affect the success rate of the restorations, and 3) The patient satisfaction is not related to dentists’ experience.

2. Materials and methods

The study was approved by the Research Ethics Committee (45344.070). Twenty-four volunteers were selected. A total of 274 ceramic restorations were placed. These included 158 anterior restorations and 116 posterior restorations teeth in maxilla (n=186) and mandible (n=88). The volunteers were aged between 28 years and 54 years.

Patients included in the study suffered from diastema, disproportioned teeth, malaligned anterior teeth, discolored teeth, and eroded or abraded teeth. The patient exclusion criteria were extensive loss of tooth structure, excessive crowding of teeth, parafunctional habits, poor oral hygiene, active periodontal problems, smoking habit, and use of removable prostheses.

2.1. Selection of professionals

Sixteen dentists of residency program in prosthodontics were selected. All professionals were divided in 4 groups with each group containing 4 dentists (n=4). The groups according to dentists’ experience were G1: up to 2 years since graduation, G2: 2-5 years since graduation, G3: 5-10 years since graduation, and G4: 10 or more years since graduation.

2.2. Clinical protocol

Before the first clinical appointment, all professionals were oriented and instructed to follow the same clinical protocol, to use the same materials, and to follow the minimally invasive tooth reduction concept to place ceramic restorations [7,14]. All professionals were part of a residency program in prosthodontics and started the course at the same time. The calibration was accompanied by theory classes about fixed partial prosthodontics involving the following topics: diagnosis, planning, minimally invasive tooth preparation concept, adhesive cementation session, occlusal adjustments, and follow up. The professionals executed all treatment steps in laboratory practice. These steps included tooth preparation, impression, adhesive cementation, adjustments, and polishing. In addition, all professionals followed clinical demonstration procedures executed by a senior professional well versed with the protocol. The level of calibration was confirmed by the Kappa test (p>0.8).

In the first clinical appointment, clinical examination and anamnesis were carried out following questions regarding the socioeconomic position and the systemic and oral health. A sequence of extraoral and intraoral photographs was followed to help with the diagnosis. Preliminary full impressions of the maxillary and the mandibular arches were made with polyvinyl siloxane impression material (Express XT, 3M, Seefeld, Germany). Based on the photographs and the casts, diagnostic wax-ups were made to improve the functional and the esthetics aspects. Subsequently, mock-up was performed, allowing patient perception of the final restoration shape, approximated color, and new dental alignment. The treatment plan was then revised and executed.

To avoid unnecessary dental reduction, silicone guides were used based on the diagnostic wax-up. All teeth preparations followed the minimally invasive technique and were performed using the silicone guides, diamond burs (fine and extra fine), and a high-speed turbine. Finishing of the surface was performed with a low speed handpiece (Kavo Koncept 1:5, Santa Catarina, Brazil). All teeth preparations were carried out with a feather edge finish line or with no finish line (the non-preparation concept) [7].

One-step impression technique was employed using double gingival retraction cords and polyvinyl siloxane impression material (Express XT, 3M, Seefeld, Germany). Digital photographs were used for tooth shade selection. All data including dental photographs, mounted casts, and diagnostic wax-ups were sent to prosthetic technicians for fabrication of ceramic restorations. During the treatment, all patients were provided with bis-acrylic resin provisional restorations (Protemp 4, 3M ESPE, St. Paul, MN, USA).

Pressed monolithic lithium disilicate ceramic (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) was used to build all ceramic restorations. All restorations were placed intraorally and were checked to ensure proper marginal fit. A try-in cementation step was performed to optimize the final appearance of translucent restorations by selecting an appropriate light-cure resin cement (Relux Veneer, Ivoclar Vivadent, 3M ESPE, St. Paul, MN, USA or Variolink Veneer, Ivoclar Vivadent, Schaau, Liechtenstein). The choice was guided by the final esthetic outcome. The finalized adhesive system was applied in both cases. For thicker (~1 mm thick) or very opaque ceramic restorations, a self-etch resin cement (Relux U200, 3M ESPE, St. Paul, MN, USA) was used.

The inner surface of all ceramic restorations was treated with 5% hydrofluoric acid for 20 seconds, rinsed, and dried. This was followed by treatment with 37% phosphoric acid etchant for 40 seconds to remove the white color on it and the restorations were again rinsed and dried. The silane coupling agent was applied (Relux Ceramic Primer, 3M ESPE, St. Paul, MN, USA) and left for 1 minute. Finally, the adhesive resin was applied (3M Single Bond Universal, 3M ESPE, St. Paul, MN, USA or Excite F, Ivoclar Vivadent, Schaau, Liechtenstein) followed by air drying to remove the excess. The adhesive was light-cured for 10 seconds (Valo Cordess, Ultradent, South Jordan, UT, USA) [18].

All teeth were previously cleaned with pumice and water. For all restorations that received Relux Veneer or Variolink Veneer, the teeth were previously treated according to the fabrication recommendations for Single Bond Universal (3M ESPE, St. Paul, MN, USA) or Excite F (Ivoclar Vivadent, Schaau, Liechtenstein), respectively. No pre-treatment of teeth was performed for restorations in which Relux U200 cement was used. All restorations were light-cured (Valo Cordess, Ultradent, South Jordan, UT, USA) for 40 seconds per tooth surface.

The final adjustments were made using a low speed hand piece (Koncept 1:5, Kavo, Santa Catarina, Brazil) with extra-fine diamond burs. Silicon burs (Exa-cerapol, Labordental Ltda., Sao Paulo, Brazil) were used for the final polishing.

2.3. Evaluation method

All restorations were fabricated in monolithic lithium disilicate (IPS e.max. Press, Ivoclar Vivadent, Schaau, Liechtenstein) by a single prosthetic technician who did not know the purposes of the study. Ninety-one all-ceramic crowns, 137 laminate veneers with feather edge finish line, and 46 laminate veneers without a cervical finish line (no-preparation veneers) were fabricated. Before cementation, thickness
of each restoration surface was measured with a digital micrometer (Mitutoyo Sul Americana Ltda, SP, Brazil).

The dentists performed the procedures under supervision of a single researcher who verified whether all clinical procedures followed the standard clinical protocol and whether all clinical appointments were completed. All dentists were permitted to consult the examiner or the Standard Operation Procedure book available for help whenever deemed necessary. Important aspects of the clinical protocol were recorded including the duration of etching the enamel and dentin with phosphoric acid, duration of ceramic etching with hydrofluoric acid, adhesive technique application, resin cement used, isolation, duration of light-curing the adhesive resin cement, ceramic adjustment, and final polishing. All negligence or imprudence-based clinical protocols were recorded for each restoration. Subsequently, outcomes of the ceramic restorations were checked and compared with the recorded information of clinical attendance to analyze the operator influence on the results.

The clinical evaluations were performed immediately after the prosthesis cementation (T0). Patients were scheduled for follow-ups at 30 days (T1), 180 days (T2), and 360 days (T3) after cementation [19]. In all follow-up appointments, standard digital photographs were obtained. The clinical outcomes of the restorations were evaluated during the follow-ups and were recorded according to the modified United States Public Health Service (USPHS) criteria adjusted for our objectives [20] (Table 1). Ceramic chipping or fracture and restoration debonding were considered clinical failures.

2.4. Fractographic evaluation

All ceramic fractures were replicated according the protocol used by Scherrer et al. [21] and were evaluated under scanning electron microscope (SEM) (EVO-LS15, Carl Zeiss Meditec AG, Jena, Germany). The SEM evaluation followed the parameters established by Mecholsky [22] and Scherrer et al. [21]. All laboratory findings were used to understand the reasons for ceramic failure and associated to clinical findings.

2.5. Statistical Analysis

Kruskal-Wallis test was applied to correlate the clinical noncompliance and the restoration failures (debonding or fracture). Mann-Whitney test was used to correlate the ceramic thickness and the fractures. Kaplan Meier analysis was used to evaluate the clinical success of the restorations. The level of significance was set at 5% (p=0.05) for all tests.

3. Result

Table 2 shows the number of cemented restorations and number of failures according to each group. The G3 group cemented the highest number of restorations followed by G1, G4, and G2. A high number of ceramic restoration failures were observed in G1 and G3. On the other hand, low incidence of failures was observed in G2. No statistically significant difference was observed regarding failures among the groups (p=0.1063).

Most of the restorations were cemented on enamel or on enamel and dentin (Table 3). No statistically significant association was observed between the fractures (p=0.4147) or debonding (p=0.9383) and the dental substrates.

Table 4 and 5 show the mean thicknesses of ceramic restorations on all surfaces. Less thickness was found in the cervical region of all restorations. The occlusal surfaces of premolars and molars also showed less thickness (Table 4 and 5).

The mean thickness and the standard deviation of ceramic restorations fractured in the anterior region (2.44 [1.7] mm) was higher than the mean thickness of intact ceramic restorations (1.63 [0.98] mm) (Fig. 1). On the other hand, the mean thickness of ceramic restorations fractured in the posterior region (1.33 [0.9] mm) was lower than the mean thickness of intact restorations in the homologous regions (1.61 [0.9] mm). However, no statistically significant association was found between ceramic restoration thickness and fracture (p=0.3107).

No statistically significant correlations were observed between the type of resin cement and debonded restorations (p=0.7334), the type of resin cement and fractured restorations (p=0.6764), the type of restoration and fractured restorations (p=0.1459), and the type of restoration and debonded restorations (p=0.3526).

The success levels were 94.5% for all-ceramic crowns, 98.5% for veneers with feather edge finish line, and 93.5% for non-preparation veneers (absence of finish line) (Fig. 2). The general success level for all types of restorations was 95.5%.

The mean duration of enamel and dentin etching using 37% phosphoric acid is shown in Fig. 3. The mean duration of ceramic etching with 5% hydrofluoric acid and the mean duration of light-curing the adhesive cement are shown in Fig. 4.

Longitudinal clinical evaluation revealed that restorations received the alpha criterion for “color satisfaction,” “tooth shape satisfaction,” “chewing comfort,” and “flossing comfort” at T1, T2, and T3 after cementation (Table 6). However, 16 restorations received the beta criterion for tooth sensitivity at T1. Three restorations received the delta criterion at T1 (one debonding and two fractures). At T2, 12 restorations received the delta criterion (9 fractures and 3 debonded restorations). At T3, all 259 restorations received the alpha criterion.

4. Discussion

A majority of clinical studies with minimally invasive treatments such as minimal tooth reduction have evaluated the clinical behavior of restorations in terms of longevity, success rates, and cumulative survival rates [1,23-25].

However, there is a lack of information about the influence of operator experience on treatment execution and consequent success or failure of ceramic restorations. In this context, blind supervision of the professionals is important to verify the operator influence on clinical findings and to correlate the restoration failures with recorded clinical errors, which in turn helps in understanding if failures were material-dependent, operator-dependent, or both.

Scientific evidences have shown about 3% failures of laminate veneers over 5 years [1,16,26-31]. The present study showed a higher number of failures than those reported in previous studies [1,28,29,32]. High number of failures were observed in G4 (16%) followed for G1 (4.8%) and G3 (3.8%). Based on these results, the first hypothesis was rejected, since the level of experience of professionals did not influence the restoration failures.

Although direct comparisons are difficult due the differences in the methodology, others authors have also reported similar results [17]. In 2009, Burque and Luccarotti [17] showed that porcelain veneer survival was not influenced by dentists’ years of experience since graduation and the experience may not play an important role in survival of veneers [33]. However, another study showed that insufficient clinical skills or operator experience resulted in more restoration failures [34].

In the present study, most of the reported failures were debonded restorations and fractured restorations. The failures occurred possibly due to noncompliance with the clinical protocol proposed to place the ceramic restorations. According our clinical records, factors described in the following discussion influenced the debonding of the restorations and ceramic fractures.

One important factor related to debonding of restorations is phosphoric acid etching of dentin. The pertinent literature states that adhesion to dentin is very complex due to its heterogeneity and phosphoric acid etching of dentin should be no longer than 15 seconds [35,36]. However, over-etching of dentin was observed in all groups including over-etching for at least five seconds in G3 and G4 and...
Table 1. Modified United States Public Health Service criterion for evaluate ceramic restorations.

| Characteristics          | Alpha (A)                                                                 | Beta (B)                                                                 | Gama (C)                                                                 | Delta (D) |
|--------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|------------|
| Color satisfaction       | Dentist and patient very satisfied                                        | Dentist and patient satisfied                                            | Acceptable color                                                          | N/A        |
| Tooth shape satisfaction | Dentist and patient very satisfied                                        | Dentist and patient satisfied                                            | N/A                                                                       | N/A        |
| Marginal fit             | There is no visible evidence of gap with explorer                        | There is a visible evidence of gap with explorer                         | The explorer penetrated in the gap                                         | Debonded or fractured |
| Second caries            | There is no evidence of caries, there is evidence of caries stains, or demineralization of tooth on tooth margins | N/A                                                                       | N/A                                                                       | N/A        |
| Sensivity                | No sensivity                                                              | Presence of sensivity                                                     | N/A                                                                       | N/A        |

Table 2. Fractures, debonding and success rate according to each group.

| Groups | Total of restorations | Fracture | Debond | Success rate under 360 days |
|--------|-----------------------|----------|--------|----------------------------|
| G1     | 105                   | 5        | 0      | 95.2%                      |
| G2     | 15                    | 0        | 1      | 93.3%                      |
| G3     | 129                   | 2        | 3      | 96.2%                      |
| G4     | 25                    | 3        | 1      | 84%                        |

Table 3. Fractures and debonding, according dental substrate.

| Dental substrate                               | Number of restorations | Fractures | Debonding | p |
|------------------------------------------------|------------------------|-----------|-----------|---|
| Enamel                                        | 63                     | 0         | 0         |   |
| Dentin                                        | 28                     | 2         | 2         |   |
| Enamel/dentin                                 | 119                    | 7         | 3         |   |
| Enamel/dentin/resin composite                 | 35                     | 1         | 0         |   |
| Enamel/resin composite                        | 5                      | 0         | 0         |   |
| Dentin/resin composite                        | 24                     | 0         | 0         |   |
| p=0.4147                                      | p=0.9383               |           |           |   |

Table 4. Mean thickness in millimeters (standard deviation) of ceramic restorations for anterior and posterior teeth for buccal, palatine, mesial, distal, and incisal faces.

| Tooth face | Buccal | Cervical | Buccal Middle | Lingual Cervical | Lingual Middle | Mesial Cervical | Mesial Middle | Distal Cervical | Distal Middle | Incisal |
|------------|--------|----------|----------------|------------------|----------------|-----------------|---------------|----------------|--------------|---------|
| Incisors   |        |          |                |                  |                |                 |               |                 |              |         |
| Canine     | 0.99 (.5) | 1.15 (.5) | 0.95 (.36) | 0.95 (.4) | 1.1 (.55) | 0.78 (.6) | 1.03 (.45) | 0.77 (.6) | 2.12 (.11) |         |
| Premolar   | 0.84 (.37) | 1.48 (.5) | 0.84 (.4) | 1.13 (.6) | 0.9 (.48) | 1.17 (.6) | 0.82 (.5) | 1.02 (.56) | 1.02 (.56) | Table 5 |
| Molar      | 0.67 (.6) | 1.31 (.58) | 0.58 (.2) | 0.92 (.31) | 0.72 (.36) | 1.06 (.8) | 0.79 (.34) | 1.06 (.64) | 1.40 (.72) |         |

Table 5. Mean thickness of ceramic restorations for posterior teeth (premolars and molars) in mm (standard deviation) for occlusal face.

| Tooth side | MDC | MTR | DTR | DBC | MTR | DTR | MLC | MTR | DTR | DLC | MTR | DTR |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Premolar   | 2.55 (.99) | 1.27 (.55) | 1.19 (.51) | -   | -   | -   | 1.87 (.96) | 1.13 (.54) | 1.16 (.54) | -   | -   | -   |
| Molar      | 2.77 (1.17) | 1.65 (.86) | 1.44 (.6) | 2.5 (.97) | 1.3 (.62) | 1.5 (.57) | 2.0 (.86) | 1.58 (.67) | 1.62 (.73) | 2.25 (.89) | 1.2 (.7) | 1.39 (.7) |

Mesiobuccal cusp (MDC); Mesial triangular ridge (MTR); Distal triangular ridge (DTR); Distobuccal cusp (DBC); Mesiolingual cusp (MLC); Distolingual cusp (DLC)

for 11 seconds in G2, resulting in loss of retention. Over-etching of dentin is considered one of the primary reasons for the degradation of dentin-adhesive interface [37], since there is a mismatch of dentin demineralization and resin infiltration. Thus, the collagen remains exposed, decreasing the mechanical properties of the hybrid layer and of dentin beneath the hybrid layer [35,36]. Corroborating this observation, debonding was observed only in the restorations placed over dentin or over dentin/enamel in the present study.

All data regarding fractured restorations collected on clinical observations were checked with fractography findings under SEM. The results suggested that early clinical failures were always associated with noncompliance with clinical protocol during the treatment.

Clinical studies have shown that restorations placed over dentin fracture more than those placed solely over enamel during an evaluation period of up to 10 years [25,29]. In the present study, 10 restorations fractured. Among them, 70% were bonded to enamel/ dentin, 20% were bonded solely to dentin, and 10% were bonded to a complex substrate (enamel/dentin/resin composite). However, there was no statistically significant correlation between dental substrate and ceramic fracture (p<0.5). On the other hand, under SEM examination, fractured ceramics always showed critical defects on the outer ceramic surface, which were responsible for beginning of crack propagation on the cervical and the proximal surfaces (Fig. 5). These critical defects may be associated with incorrect occlusal adjustments and inadequate ceramic polishing [38-40]. In fact, defects on the outer surface of all fractured restorations were initiated due to the use of high speed for occlusal adjustment and the absence of an ideal ceramic polishing protocol. Thus, the second hypothesis was rejected, since noncompliance with clinical protocol influenced the success of the restorations.

Occlusal adjustments executed with highly abrasive diamond burs might be an increase in temperature on the ceramic surface with
increase in speed [41], consequently decreasing the flexural strength of
the ceramics [42]. The actual clinical protocol for ceramic adjustment
should be executed in slow rotation and using fine granulation burs
under water irrigation. Such a protocol results in decreased roughness
and decreased heat transmission to the ceramic surface [43,44].
Subsequently, polishing of the ceramic surface with silicon diamond
burs must be executed, since the surface texture acquired by this
process is closer to the glaze produced in lab [38,39], which prevents
critical defects and crack propagation.

The uniqueness of the present study was the evaluation of ceramic
restorations fabricated by 16 dentists with varying professional
experience. The lower success level recorded in the present study (94%)
after 12 months might reflect the characteristics of the methodology.
Most of the prospective clinical researches on this topic have
evaluated restorations placed by a single highly experienced operator
[3,4,32,45,46] or few highly experienced operators [1,2,47] and may
have overestimated the success rate of ceramic restorations executed
by majority of the dentists. In the present study, only the veneers with
featheredge preparations showed success levels (98.5%) comparable to
those reported in the aforementioned studies.

However, important information was gained in the present study
regarding of the patient satisfaction. The satisfaction level observed
was higher than that reported by Granell-Ruiz [16] who found 97%
satisfaction with conservative veneer treatment. Based on this finding,
the third hypothesis was rejected, since professional level of experience
did not influence patient satisfaction.

The results of the present study revealed that noncompliance with
the clinical protocol was an important factor for premature operator-dependent failures of minimally invasive ceramic restorations. Neglecting some factors such as occlusal adjustments with diamond burs mounted on a high-speed turbine and final polishing may be related to the less amount of experience of the professionals with the proposed clinical protocol. However, other factors such as dentin etching with phosphoric acid and dentin humidity before adhesive application may be related to the lack of proper duration of conditioning and subjective character of dentine moisture, respectively. Although valuable information was obtained, long-term follow-ups are necessary for a better understanding of the clinical behavior and the long-term clinical success of ceramic restorations fabricated using

Table 6. Longitudinal evaluation of ceramic restorations following established of USPHS (United States Public Health Service).

| Time(days) | Color satisfaction | Tooth shape satisfaction | Comfort to chew | Comfort to floss | Sensitivity | Fracture | Marginal fit | Debond | Second Caries |
|------------|--------------------|--------------------------|----------------|----------------|-------------|----------|-------------|--------|--------------|
| 0          | 274 A              | 274 A                    | -              | 274 A          | 274 A       | 274 A    | 274 A       | -      | 274 A        |
| 30         | 271 A              | 271 A                    | 271 A          | 271 A          | 274 A       | 255 A    | 274 A       | -      | 274 A        |
| 16 B       | 271 A              | 271 A                    | 271 A          | 271 A          | 274 A       | 274 A    | 274 A       | -      | 274 A        |
| 1 D        | 271 A              | 271 A                    | 271 A          | 271 A          | 274 A       | 274 A    | 274 A       | -      | 274 A        |
| 2 D        | 271 A              | 271 A                    | 271 A          | 271 A          | 274 A       | 274 A    | 274 A       | -      | 274 A        |
| 180        | 259 A              | 259 A                    | 259 A          | 259 A          | 259 A       | 259 A    | 259 A       | -      | 259 A        |
| 9 D        | 259 A              | 259 A                    | 259 A          | 259 A          | 259 A       | 259 A    | 259 A       | -      | 259 A        |
| 3 D        | 259 A              | 259 A                    | 259 A          | 259 A          | 259 A       | 259 A    | 259 A       | -      | 259 A        |
| 360        | 259 A              | 259 A                    | 259 A          | 259 A          | 259 A       | 259 A    | 259 A       | -      | 259 A        |

A (Alfa); B (Beta); C (Charlie); D (Delta)

Fig. 5. A – Buccal view of fractured ceramic restoration of an upper first premolar; B – SEM image of fracture under x 23, and interested area inside the square (b); C – Representative image of incisal edge of fractured ceramic (x100); D – Representative scheme of C image, showing all fractographic marks (dc = origin of fracture localized on external surface of buccal cuspid; m = mirror area; h = hackles indicating the fracture propagation direction; al = arrest lines). x100
the minimally invasive approach.

5. Conclusion

Based on the clinical findings of the present study, it was possible to conclude that professional experience was not a decisive factor for patient satisfaction and clinical success of minimally invasive ceramic restorations. However, noncompliance with the clinical protocol was strongly associated with early ceramic restoration failures. Thus, it could be affirmed that early ceramic failures were operator-dependent.

Conflict of interest statement

The authors do not have any conflict of interest. All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.

Acknowledgment

The authors would like to thank Sao Paulo State Research Foundation – FAPESP #2013/11938-0 for the research grant.

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