UNIVERSIDADE FEDERAL DE MINAS GERAIS
FACULDADE DE ODONTOLOGIA

INFLUÊNCIA DA TRANSMISSÃO DE LUZ ATRAVÉS DE PINOS DE FIBRA NA MICRODUREZA E RESISTÊNCIA ADESIVA DO CIMENTO.

LUÍS FERNANDO MORGAN DOS SANTOS ALVES

BELO HORIZONTE
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LUÍS FERNANDO MORGAN DOS SANTOS ALVES

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Orientador: Prof. Dr. Luiz Thadeu de Abreu Poletto
Co-orientador: Prof. Dr. Rodrigo de Castro Albuquerque

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SUMÁRIO

RESUMO

O objetivo deste estudo foi correlacionar a quantidade (Artigo 1) e influência da transmissão de luz através de pinos de fibra na microdureza Knoop (KHN) e na resistência adesiva (RA) (Artigo 2) em um cimento resinoso autoadesivo de dupla polimerização. Quatro pinos de fibra de diferentes tipos e fabricantes foram utilizados para a análise quantitativa da transmissão de luz. Para KHN e RA cinco pinos também de diferentes tipos e fabricantes representaram um grupo teste. Para as análises quantitativas e da KHN uma matriz metálica foi desenvolvida simulando o posicionamento do cimento ao redor do pino após o processo de cimentação. Três profundidades distintas foram avaliadas. A resistência ao deslocamento, que proverá dados de RA, foi realizada utilizando incisivos bovinos. Para este teste, após cimentação dos pinos, cortes transversais da porção radicular dos dentes no espaço do pino originaram discos de 1mm. Os valores obtidos foram submetidos à análise estatística pelos testes de ANOVA e de Tukey's, ao nível de 95% de confiabilidade ($P<0,05$) para a análise quantitativa da transmissão radial de luz, KHN e RA. A análise estatística da quantidade de energia luminosa transmitida mostrou que depende do tipo de pino e que esta reduz com o aumento da profundidade. Para KHN, os resultados não mostraram diferenças estatísticas para os diferentes pinos e terços. Para RA, na somatória dos terços, um pino translucente apresentou os maiores valores. Análises comparativas entre os terços de cada pino também mostrou diferenças estatisticamente significantes, enquanto que comparações dos terços do mesmo pino não apresentaram diferenças.

ABSTRACT

The aim of this study was to correlate the amount (Article 1) and influence of the transmission of light through fiber posts in microhardness (KHN) and bond strength (BS) (Article 2) in a dual self-etch resin cement. Four posts of different types and manufacturers for quantitative analysis were used. For KHN and BS five also deifferent types and manufacturers represented a test group. For the quantitative analysis of the KHN, a metal matrix was developed to simulate the radial positioning of the cement after the process of cementation. Three different depths were evaluated. The resistance to displacement, which will provide data of BS was performed using bovine incisors. For this test, after cementation, cross sections of the root portion of teeth in space of the post originated 1mm discs. The values were statistically analyzed by ANOVA and Tukey's at 95% confidence ($P < 0.05$) for quantitative analysis of the radial light transmission, KHN and BS. Statistical analysis of the amount of light energy transmitted showed that it depends on the type of post and it reduces with increasing depth. To KHN, the results showed no statistical differences for the different posts and thirds. For BS, when the thirds were summed, a translucent post showed the highest values. The comparative analysis between the thirds of each post also showed statistically significant differences, while comparisons of the same post-thirds did not show any differences.

1 INTRODUÇÃO

Na busca pelo conhecimento científico, que elucida hipóteses e norteia procedimentos clínicos surgem, a cada etapa vencida e perguntas respondidas, novos questionamentos acerca dos procedimentos e técnicas empregadas. A evolução dos estudos e os procedimentos para cimentação de pinos intrarradiculares em dentes tratados endodonticamente retrata esta contínua e necessária busca do conhecimento científico, principalmente em relação aos materiais e técnicas utilizados.

Os pinos de fibra, inclusive os transluncentes, oferecem várias características favoráveis, das quais podemos salientar módulo de elasticidade semelhante ao da dentina e possibilidade de adesão ao dente e ao material de preenchimento (Asmussen et al, 1999; Albuquerque et al., 2003), justificando sua utilização clínica.

De maneira unânime, a literatura cita com principal função de um pino intra-radicular a retenção da restauração ou material de preenchimento/restauração. Partindo deste conhecimento, é plausível e justificável tamanha dedicação de autores de todo o mundo sobre esse tema.

Não obstante haverem evidências científicas de que o principal fator para o sucesso da fixação de pinos de fibra intrarradiculares esteja ligado predominantemente à retenção friccional, os estudos científicos em sua maioria são destinados à cimentação propriamente dita desses materiais. Entretanto, Naumann e colaboradores , em 2008, mostraram, em estudo *in vitro,* que o uso de materiais adesivos para cimentação é mais confiável para suportar as forças simuladas em comparação com o uso da cimentação convencional não adesiva. Dessa forma, além da um pino bem adaptado ao canal radicular preparado, o uso de cimentos adesivos também parece contribuir para o sucesso destes trabalhos.

Em relação aos materiais adesivos, os do tipo resinosos são hoje os mais estudados. No que tange a esses materiais, três categorias quanto aos métodos de polimerização são encontradas:

cimentos autopolimerizáveis, fotopolimerizáveis e de dupla polimerização. Aos autopolimerizáveis é inferida a desvantagem de possuírem o tempo de trabalho limitado. Já os fotopolimerizáveis dependem da luz. Considerando que o acesso da luz às partes mais profundas do conduto radicular é limitada (Morgan et al., 2008, Yi-ching HO et al., 2011) o uso de cimentos de dupla polimerização tem sido recomendado (Ceballos et al., 2007).

Outra tendência que tem sido percebida é o surgimento e uso de cimentos resinosos auto-adesivos de dupla polimerização. Seu uso traz vantagens baseadas na diminuição de passos clínicos, facilidade técnica, diminuição da possibilidade de erros e do tempo clínico gasto nos dos procedimentos de cimentação.

Com o objetivo de transmitir energia luminosa em quantidade suficiente para polimerização de cimentos resinosos fotopolimerizáveis ou de dupla polimerização até as regiões mais profundas do canal radicular pinos de fibra de vidro translucentes foram desenvolvidos. Porém, poucas informações sobre a quantidade de luz transmitida radialmente e a influência da transmissão destas quantidades de luz através de pinos de fibra translucentes na microdureza Knoop (KHN) e resistência adesiva (RA) de cimentos resinosos de dupla polimerização tem sido relatadas na literatura. Outro aspecto importante é que, dentre os estudos até então publicados, existe uma grande variação quanto ao tamanho e diâmetro dos pinos testados. Padronizar estas variáveis, para que uma correlação precisa destes dados possa ser realizada, é importante passo no conhecimento do potencial e efeito da quantidade de luz transmitida através das diferentes composições de pinos de fibra.

2 JUSTIFICATIVA E RELEVÂNCIA

Cimentos resinosos fotopolimerizáveis ou de cura “dual” para cimentação de pinos de fibra intrarradiculares requerem uma quantidade adequada de energia luminosa para polimerização até regiões mais profundas do conduto. A adequada conversão de monômeros em polímeros proporciona melhor desempenho desses cimentos no exercício de suas funções, fundamentada principalmente na retenção do material cimentado. Dessa forma, pinos que tem a promessa de transmitir luz em sua extensão, denominados translucentes, surgem com o objetivo de polimerizar o cimento até nas regiões mais profundas. Torna-se importante então, a partir do exposto, determinar a quantidade de luz transmitida, a microdureza e a resistência adesiva nas diferentes profundidades, para cimentos resinosos de dupla polimerização, proporcionada pelos pinos de fibra translucentes, principalmente nas regiões mais profundas.

3 OBJETIVO

O objetivo deste estudo é investigar e estabelecer uma relação precisa da quantidade de luz transmitida através de pinos de fibra e seu efeito na KHN e na RA de um cimento resinoso de dupla polimerização.

4 ARTIGOS CIENTÍFICOS

4.1 ARTIGO 1

Title: Radial transmission of light through fiber posts

Abstract

Introduction: The correct photoactivation of resin cements for the cementation of dental posts depends on the amount of luminous energy that is transmitted radially. **Methods:** The present study aimed to perform a quantitative investigation of the radial transmission of light through four different posts of two types. The analysis demanded both a customization of metallic apparatus matrices according to the exact dimensions of each post and the measurement of luminous energy at three different depths by means of a digital volt-ampere meter. This study involved the ANOVA and Tukey Tests (p,0.05). **Results:** The amount of radially transmitted luminous energy depends on the type of post used. Nevertheless, increases in depths account for significantly reduced amounts of radially transmitted light. **Conclusion:** The luminous intensity that is radially transmitted to the posts is reduced to levels that are insufficient for polymerization, especially in the apical third of the root, thus confirming the hypothesis of this paper.

Keywords: dental posts, light transmission, dental material.

Introduction

The use of pre-molded posts in tooth restoration after root canal treatment is well documented in the literature. Such posts are commonly used to retain the filling material and reduce the possibility of subsequent fracture of the tooth and restoration complex (1-3).

Fiber posts exhibit some interesting features justifying their clinical usage, which include an elasticity module similar to that of the dentine and chemical characteristics compatible with Bisphenol-Glycidyl Methacrylate (Bis-Gma) and with resins commonly used in adhesive procedures (4).

Regarding resin cements and their respective types of polymerization, there are three options available on the market: self-cured, light-cured, or dual-cured resin cements. Taking into account both the polymerization mechanisms of such cementation systems (5) and the evidence that translucent fiber posts do not transmit enough luminous energy (6-7), the use of self-cured materials have proven to provide more reliable cementation. However, the use of light-cured resin cements or dual-cured materials have been recommended by manufacturers for use in association with translucent fiber posts.

The literature describes the undesirable effects on incomplete polymerization which include toxicity, poor mechanical properties and adhesive properties (2, 7, 8, 9-12).

This study aims to quantitatively investigate the radial transmission of light through fiber posts.

Material and methods

The present study involved four different fiber posts of two types. Table 1 shows their types and respective manufacturers.

Table 1 – Description of the posts used.

Group	Manufacturer	Type	Chemical Composition
T1	FGM (Brazil)	Translucent	Glass Fibers(80%±5), epoxy resin(20% ± 5), silica, silane and polymerising promoters.
T2	Bisco INC(USA)	Translucent	Glass Fibers(55%), epoxy(45%).
C1	Ângelus(Brazil)	Conventional	Glass Fibers(87%), Epoxy resin(13%).
C2	Ângelus(Brazil)	Conventional	Carbon Fibers(72%), epoxy(28%)

As shown in the table, White Post DC (FGM, Joinville, SC-Brazil) and DT Light Post (Bisco, Inc, Schaumburg, IL-USA) with similar compositions but with different amounts of chemical components, represent translucent (T) type, T1 and T2 respectively. Exacto (Ângelus, Londrina, Pr-Brazil) and Reforpost Carbon Fiber (Ângelus, Londrina, Pr-Brazil) with different compositions but opaque, represent conventional (C) type, C1 and C2 respectively. One post was used for each group.

For assessment purposes, all the posts were cut while being cooled at the standard height of 16 mm by a precision machine (Isomet 1000, Buehler, Lake Bluff, IL-USA).

The assessments targeted three different depths, namely: (i) cervical third (CT), at a 4.1-8mm depth; (ii) middle third (MT), at an 8.1-12mm depth; and apical third (AT), at a 12.1-16mm depth.

To assess the three post regions, a metallic apparatus matrix was designed and manufactured to support the posts, a digital power meter (Nova; Ophir, Hicksville, NY-USA), and the tip of a curing light unit while also obstructing the influence of external sources of light. Such a metallic apparatus consisted of two parts: (i) a frame, which contained the posts and the volt-ampere meter; and (ii) an external cylinder, which enveloped the other part while also incorporating the curing light unit at the top (Figure 1).

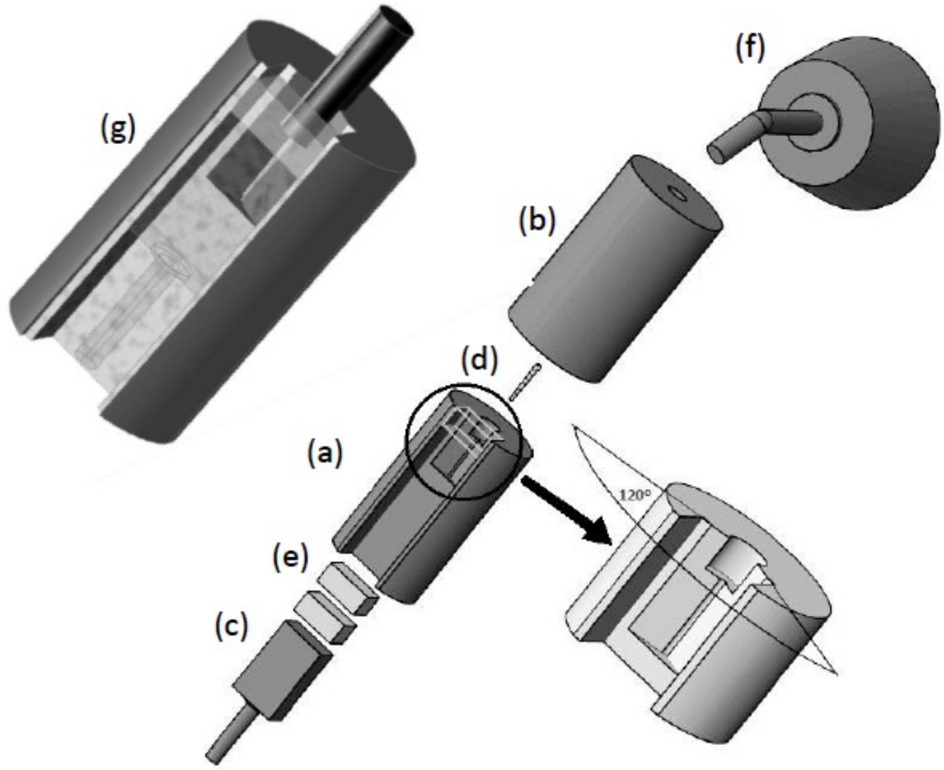

Fig. 1: (a) frame; (b) external cylinder; (c) volt-ampere meter; (d) post; (e) metallic blocks; (f) light curing tip; (g) set of apparatus. Patented CTIT/UFMG (BR 20 2012 015542 2).

The post space frame was manufactured in the exact dimensions of each post by means of electroerosion machining. How the post tested have different shapes, one frame for each post was manufactured. Aimed at standardizing the quantitative radial reading, each third of the posts contained a 120-degree lateral side opening.

AT was the first third to be assessed, followed sequentially by MT and CT. The measures of each third were taken separately from the measures of the remaining thirds. For an accurate separate assessment of each third, strategically positioned 4 mm metal blocks determined the internal position of the volt-ampere meter in relation to the posts.

A 60-second light exposure was used, and the luminous intensity was recorded at 2 and 59 seconds to establish a mean. Ten measurements were taken for each depth assessed. To standardize the luminous intensity, the light source instrument (Curing Light 2500; 3M ESPE, St Paul, MN) was preheated with five 60-second cycles. Between each measurement, the light source was left at rest for 1 minute 30 seconds, which is the time necessary for the cooling fan to automatically turn off. The set consisting of the curing light unit, the matrix, the post and the digital reader remained still throughout the assessments. The metal matrices also had their radial transmission of light tested without posts.

Equations 1 and 2 were used to calculate the luminous intensity per area unit at each depth. Equation 1 provides the area of exposure from a trunk of cone to the volt-ampere meter scanner (considering a 120-degree side opening). In this equation, g [m] is the generatrix, R [m] is the large base radius, r [m] s the small base radius, and h [m] is the height of the truck of cone.

$$A = \frac{1}{3}\pi g([R + r)]$$

$$A = \frac{1}{3}\pi g(R + r)$$

which further develops to:

$$A = \frac{1}{3}\sum \pi \sqrt{(R - r)^2 + h^2}(R + r)$$

$$A = \frac{1}{3}\sum \pi \sqrt{((R - r)^2 + h^2)([R + r)]}$$

Equation 1.

Equation 2 represents the luminous flux per area unit, I_R [W.m^{-2}]. In this equation, A [mm^2] derives from Equation 1, and I [W] is the total luminous flux from a given section of a post of height h [m], the measurement particularly targeting one third of the surface area of this section (120-degree side opening).

$$I_R = I/A$$

Equation 2

ANOVA and Tukey statistical tests assessed the results at $p<0.05$ to compare the thirds and the groups.

Results

Table 2 shows within-group means, standard deviations and statistical analysis of the amount of light radially transmitted through the fiber posts at the different investigated depths.

Table 2. Whithin-group means, standart deviations (SD), statistical tests of the amount of light and light reflected by matrixes.

Type of post	Position		
	Apical third (12 mm depth)	**Middle Third** (8 mm depth)	**Cervical Third** (4 mm depth)
T1	5,766 ± 0,046Ba	6,515 ± 0,145Bb	14,156±0,093Bc
T2	6,164± 0,125Ca	1,433 ± 0,100Cb	14,319±0,216Cc
C1	0,003 ± 0,000Aa	0,002 ± 0,000Ab	0,030±0,000Ac
C2	0,001 ± 0,000Aa	0,001 ± 0,000Ab	0,035±0,000Ac
Matrix of respective posts			
T1	0,484 ± 0,011E	0,202 ± 0,001D	0,459±0,005D
T2	0,226 ± 0,004F	0,187 ± 0,003D	1,614±0,012F
C1	0,160 ± 0,017D	0,025 ± 0,002A	0,217±0,016E
C2	0,142 ± 0,013D	0,030± 0,003A	0,398±0,032D

*ANOVA and Tukey tests. Different capital-letters stand for statistically significant cross-group differences within each column/third (P<0.05). Different lower-case letters stand for statistically significant differences across the depths (thirds) within each line (p<0.05).

For AT, the cross-group analysis points to higher luminous energy in T2, followed by group T1. Groups C1 and C2 were equal and shows lowest values. For MT, the analysis reveals higher values for Groups T1 and T2, the difference being significant between them. Groups C1 and C2 presented the lowest values. For CT, Group T2 shows higher luminous energy than T1, while Groups C1 and C2 once again presented the lowest values.

As for the analyses of the metallic apparatus without posts, the results point out that the amount of light reflected by such containers did not significantly interfere in the values found for their respective posts.

Finally, within-group analyses of the different thirds showed significant reductions in the luminous intensity as the result of increased depths.

Discussion

Although recent studies have revealed negative results concerning the amount of luminous energy transmitted through translucent posts (5-7,10,13-14), their manufacturers promised a sufficient transmission of light for the polymerization of both light-cured and dual-cured resin cements. This variable, as well as the characteristics of a root dentine (15-17), produces a direct impact on the cementation quality along the adhesive interfaces of a post (18-20), especially since the quality is dependent on both the cement-post placement and the amount of luminous energy applied for the polymerization of dual-cured and light-cured resin cements (21, 22).

The values obtained revealed low luminous intensity across all investigated depths, which corroborate a hypothesis raised in a previous studies (6, 23). Both studies attest to reduced luminosity as the result of increased depth, regardless of the higher raw values found in the present research. The reason for such differences seems to rely on the principles of transmittance, refractance, and absorbance. Since the previous study assessed end regions of crosscut posts, the vertical orientation of the fibers may have led to transmittance in the transmission of light through the posts. On the other hand, the present research assessed the energy radially reflected through the post, which accounts for the major impact of refractance on the results. The size and concentration of inorganic particles, as well as the pigment color of the resin matrix, are related to the process (24). Finally, the absorbance phenomenon, supported by the Lambert-Beer Law, influenced the results of both studies.

The aim of this study was investigated the type of post and yours different composition and not to compare between manufacturers. Others fiber posts do not included due the similarity basic composition with these ones tested.

The investigated posts contained different diameters and surface shape. Assuming that the amount of light transmitted through the post is directly related to its diameter (25) and considering that this study was aimed at exclusively analyzing the materials, the calculation of light transmission through each post built on the standardized area was exposed to the volt-ampere meter (120 degrees), as explained through the Equation 1.

The results from Group T2 for the MT depth showed unexpected result until then. The MT depth encompasses the 8.1-12mm region of the post, show less light transmitted than the AT. To exclude any errors in methodology or problems with the manufacture of the post, measures of this third of this post were performed in triplicate with 3 different posts. The results were similar. In TM region this post is remarkably conic and the longitudinal orientation of the fibers appears to be the most likely hypothesis to explain this phenomenon, i.e., in TM region of this post have less translucent fiber endings, which act as wave guide length, so it is acceptable for smaller amounts of light were recorded.

The methodology of this study prevented the introduction of any light wavelengths along the optical path of the post that had not been axially introduced through the upper end of this post. The electroerosion machining of the matrices resulted in smooth and only slightly reflective surfaces, which did not interfere in the results (Table 2). Despite the low rates, this finding proves that the posts do in fact transmit light radially.

The standardized light emission proved to establish a reliable relationship among the results, which validated the means shown in this paper. The use of only one post per group does not compromise these results since the previous study (6) and our pilot study pointed to similarities between different posts from the same manufacturers. The applied methodology also proved to be efficient.

The amounts of radial transmission of luminous energy are seemingly insufficient to offset the clinical amount of time used. The values obtained for the translucent posts would demand excessively long periods of time for accurate clinical practice as show in other study (6).

In sum, the results of this study point out that:

- The amount of radial transmission of luminous energy depends on the type of post.
- There is a reduction in amount of radial transmission at greater depths.

Financial Affiliation

I/we affirm that I have no financial affiliation (e.g., employment, direct payment, stock holdings, retainers, consultant ships, patent licensing arrangements or honoraria), or involvement with any commercial organization with direct financial interest in the subject or materials discussed in this manuscript, nor have any such arrangements existed in the past three years. Any other potential conflict of interest is disclosed.

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4 ARTIGOS CIENTÍFICOS

4.2 ARTIGO 2

Title: Influence of light transmission through fiber posts on the microhardness and bond strength

Authors: Morgan LFSA, Gomes GM, Poletto LTA, Ferreira FM, Pinotti MB, Albuquerque RC.

Abstract

Introduction: The aim of this study was to investigate the influence of light transmission through fiber posts in microhardness (KHN) and bond strength (BS) from a dual cured resin cement. **Methods:** Five fiberglass posts of different types and manufacturers represent a test group for the analysis of KHN (N=5) and BS and their displacement under compressive loads (N = 8). For the analysis of KHN a metallic matrix was developed to simulate the positioning of the cement after the cementation process intra radicular posts. The resistance to displacement, which will provide data of BS was measured using bovine incisors. After cementation, cross sections of the root portion of teeth in space led to post 1mm discs that have been tested for BS. The values were statistically analyzed by ANOVA, followed by Tukey's (P <0.05) between groups for KHN and BS. **Results:** The results showed no statistical differences for the different posts in KHN. For BS, the sum of thirds, a translucent post showed the highest values. Comparative analysis between the thirds of each post also showed statistically significant differences when comparisons of the same post-thirds showed no differences. **Conclusion:** For the cement used, the amount of light transmitted through the post did not influence the KNH nor the BS significantly, among the different posts and thirds evaluated.

Key Words: light transmission, dental posts, microhardness, bond strength.

Introduction

The use of pre-fabricated posts in the reconstruction of endodontically treated teeth, whose main objective is to retain the material reconstruction and minimize the occurrence and complexity of fractures, is well established in the literature (1). Clinically, the mechanical and chemical characteristics of fiber posts justify their usage (2).

In relation to resin cements, three options regarding the method of polymerization are available: self-polymerizing, light-cured or dual polymerization (dual). Understanding the mechanism of polymerization of these systems (3) the choice of materials that do not depend on light seems to be more reliable for cementing intra radicular fiber posts.

To investigate the capability of transmitting light by translucent post is the target of several recent authors (4-9). Most studies point to the decrease in light intensity (LI) by increasing the root depth. Quantitative assessments of LI, hardness, elastic modulus and degree of conversion can be found in these works. Undesirable effects of incomplete polymerization of the resin cements are of biological (10-12) due to toxicity, and mechanical (8,9,13-15), due to low bond strength values are described in the literature.

The aim of this study is to investigate the effect of light transmission through fiber posts in Knoop microhardness number (KHN) and bond strength (BS) of a dual resin cement. The null hypothesis is that there is no statistically significant difference in KHN and BS for different depths evaluated for the dual resin cement following cementation of translucent posts.

Material e Methods

Five different fiber posts of two types and one resin cement were involved (Table 1).

Table 1 – Description of the posts and cement used.

Post	Manufacturer/Lote	Type	Quimical composition
T1	FGM Produtos Odontológicos (Brazil)/140410	Translucent	Glass Fibers (80% ± 5), epoxy resin (20% ± 5), silica, silane and polymerising promoters.
T2	Bisco, INC (EUA)/0800007811	Translucent	Glass Fibers (55%), Epoxy (45%).
T3	Ivoclar-Vivadent (Liechtenstein)/M72483	Translucent	TetraethyleneglycolDimethacrylate (7.6%), Urethane Dimethacrylate (18.3%), Silicium Dioxide (0.9%), Ytterbium Fluoride (11.4%), catalysers and stabilisers (<0.3%). Glass Fibers.
C1	Ângelus (Brazil)/14818	Conventional	Glass Fibers (87%), Epoxy resin (13%).
C2	Ângelus (Brazil)/14874	Conventional	Carbon Fibers (79%), Epoxy Resin (21%).
Resin Cement			
Rely-X Unicem	3M ESPE (USA)/372990	Self-etch/ Dual Cure	Powder: glass particles, initiators, sílica, substituted pyrimidine, calcium hidroxide, peroxide composite and pigment; liquid: metacrylate phosphoric acid Ester, dimethacrylate, acetate, stabilizer and initiator.

White Post DC (FGM, Joinville, SC-Brazil), DT Light Post (Bisco, Inc, Schaumburg, IL-USA) and FRC Postec Plus (IvoclarVivadent, Liechtenstein) with similar compositions but with different amounts of chemical components, represent translucent (T) type, T1, T2 and T3 respectively. Exacto and Reforpost Carbon Fiber (Both Ângelus, Londrina, Pr-Brazil) with different compositions but opaque, represent conventional (C) type, C1 and C2 respectively. The posts were cut to standard height of 16 mm for both analysis, KHN and RA.

KHN measurements

The assessments targeted three different depths, namely: cervical third (CT), at a 4.1 to 6.8mm depth; middle third (MT), at an 8.8 to 11.5mm depth; and apical third (AT), at a 13.5 to 16mm depth.

A metallic apparatus matrix was designed and manufactured to support the posts, resin cement, and the tip of a curing light unit. Such a metallic apparatus consisted of four parts as showed in figure 1.

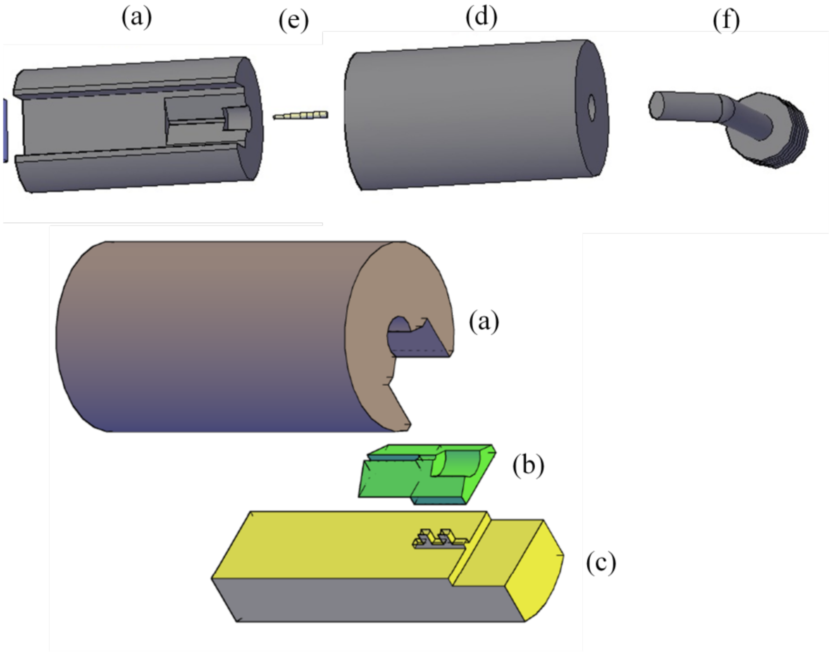

Figure 1. Metallic matrix: (a) a frame, which contained the posts (e), (b) a support to standardize the position and volume of resin cement, (c) a support to standardize the length of each three third deep post regions and stabilize the set, (d) and an external cylinder, which holds the other part as well as incorporates the tip of curing light unit (f) at the top and also obstructs the influence of external sources of light. Patented CTIT/UFMG (BR 20 2012 015542 2).

The frames were manufactured in the exact dimensions of each post by means of an electro erosion machining. Aimed at standardizing the quantitative radial light transmission, each third of the posts contained a 120-degree lateral side opening. The three thirds, were supposed to be assessed simultaneously. The measurement of all thirds, one at a time, was possible because the matrix allowed the removal of the resin cement blocks, separately, after polymerization, without destroying them. The matrix's internal structure provided an adequate separation of each third, which permitted their accurate evaluation. Each one was 1,6mm wide and 2,70 mm length. The major concern about this matrix was that the cement was inserted directly in projected spaces, in order to minimize the formation of bubbles. The posts were isolate from cement by a polyester strip.

The time of light exposure was 40 seconds, and the LI remained above 420mW/cm^2. The light curing unit used was Curing Light 2500(3M ESPE, USA). The set consisting of the curing light unit, the matrix, the post and the resin cement remained still throughout the assessments.

After ten minutes, including 40s photopolymerization, the specimens were removed from the matrix and were immediately included in pre-molds (Buehler, USA) with crystal resin with black pigment and were poured into the device by using a Cast N'vac (Buehler, USA). After the cure of crystal resin, the specimens were removed from the pre-molds and stored dry, out of reach of light during 7 days. The surface to be analyzed was sequentially polished with # 320 to 1200-grit SiC papers and felt with diamond polish paste (Buehler, USA). A control group, using T1, was made of the same method but without a photopolymerization.

KHN measurement was performed by a Micromet 5104(Buehler, Japan) using a static load of 50g for 10s. Sequentially, three indentations were performed for each third of each group. The values were obtained from the reading of the average of three indentations oriented long axis of the post on each third.

BS measurements

Twenty five bovine incisors, approved by the Ethics Committee of Animal Experiments protocol 19/2010, had the crown cut in an Isomet 1000 (Buehler, IL, USA) machine which determined the pattern of root height 19mm. The preparation of the root canals was standardized with Gates-Glidden drills# 3(DentsplyMailleferSA,Baillaigues, Switzerland). The conducts were filled by lateral condensation technique, which was used with the cement Sealer26 (Dentsply, Tulsa, OK, USA) (14). After seven days, the roots had the post space prepared with 14mm deep and wide drills (DentsplyMailleferSA,Ballaigues, Switzerland) 1, 2 and 3. The T1 group had the root canals formatted by their drill which come in their own kit. One week after cementation, the roots were embedded in acrylic resin Duralay (Reliance, Worth, IL, USA) contained in tubes of polyvinyl chloride and sectioned by a cutting machine (Isomet) transversely in longitudinal axis, from cervical to apical root six discs of 1 millimeter each were obteined. Two discs of the TC, at 3.0 and 4.0mm, two of the TM, at 7.0 and 8.0 mm and two of the AT, at 11.0 and 12mm. The specimens were stored in sterile distilled water at room temperature.

The dimensions of the discs were calculated to obtain the bonding area in mm^2 by applying the formula: π(R +r) [(h2 +(R -r) 2] 0.5, whereπ=3.14, R represents the largest radius millimeters (mm), r minor radius (mm) and h disc height (mm).

The specimens were subjected to compressive loads on the post in the apico-cervical direction of its longitudinal axis with the universal testing machine (AG-I, Shimadzu Autograph, Brazil) with a speed of 0.5mm/min until the moment of displacement. The results in Newton (N) were transformed to Megapascal (MPa) (Newton/mm^2 =Megapascal) (16)

Data treatment

Pooled data from three thirds were used to assess if differences between groups, as well as data gathered from each third were used to verify differences between them (one-way ANOVA). Later, the results were analyzed for each post depending on the different thirds and evaluated according to the presence of interaction effects (two-way ANOVA) and Tukey's test (P <0.05).

Results

To KHN, the analysis showed no statistical difference for the data sets of three thirds, for data collected for all groups, and among thirds (one-way ANOVA). The analysis of the results for each post, depending on the different thirds and the presence of interaction effects showed no significant differences (two-way ANOVA). The Tukey post-test showed no individual differences (p <0.05) (Tab 2)

Table 2. Means, median and Standard Deviations of experimental and control groups of different thirds and posts for KHN.

	Cervical third			**Middle third**			**Apical third**			
Post	mean	SD	median	mean	SD	mediana	mean	SD	median	Pooled
Control	58.16	5.38	60.20^{Aa}	58.0	1.88	57.90^{Aa}	58.40	3.18	57.50^{Aa}	58.18
White post DC	57.14	±13.72	63.40^{Aa}	53.52	±12.19	61.10^{Aa}	54.28	±13.51	61.00^{Aa}	55.01
DT Light Post	57.30	± 3.75	56.50^{Aa}	57.42	± 6.58	59.20^{Aa}	56.24	± 4.75	58.20^{Aa}	56.99
FRC Postec Plus	49.62	± 4.62	47.50^{Aa}	50.28	± 4.40	49.70^{Aa}	48.06	±10.97	43.70^{Aa}	49.32
Exacto	56.70	± 7.73	61.70^{Aa}	57.04	± 9.30	59.70^{Aa}	56.78	± 7.87	55.60^{Aa}	56.84
Reforpost Carbon Fiber	50.82	± 4.72	51.80^{Aa}	50.70	± 2.95	52.40^{Aa}	47.94	± 3.33	48.30^{Aa}	49.82

Different letters indicate significant differences ($p<0.05$). Lower case letters compare values per row and capital letters compares values per column.

Analysis of the results of BS showed a significant difference for the data sets of three thirds used, where the posts where T1 and C2 showed the highest values. Similarly, the data gathered for the 5 posts showed differences between the thirds (one-way ANOVA). The analysis of the results to compare the different thirds for each post individual and the presence of interaction between the effects, did not differ significantly (two-way ANOVA) (p <0.05). (Tab 3).

Table 3. Means and Standard Deviations of experimental groups of different thirds and posts for bond strength.

Post	**Cervical third**		**Middle third**		**Apical third**		**Pooled**	
	Mean	SD	mean	SD	mean	SD	Mean	SD
White post DC	14.77aA	2.68	12.64aA	3.14	14.14aA	4.35	13.86A	3.49
DT Light Post	9.64aB	3.37	10.07aB	2.57	12.10aA	5	10.42B	3.47
FRC Postec Plus	9.62aB	2.67	11.02aB	2.77	6.19aB	4.63	9.23B	3.79
Exacto	9.62aB	2.76	8.29aC	1.91	13.39aA	3.78	10.20B	3.47
Reforpost Carbon Fiber	13.42aA	3.86	12.45aA	2.5	6.95aB	2.67	10.97B	4.20

Different letters indicate significant differences (p<0.05). Lower case letters compare values per row and capital letters compares values per column.

Discussion

The KHN tests are a good indirect method to evaluate relative degree of polymerization for resin-base materials (17). In this way, these tests are frequently used to evaluate the physical propriety of these materials (18, 19). For evaluating BS fiber posts to root dentine, push-out tests seem to be reliable. The perpendicular sectioning of root-post sets 1-mm-thick sections, used in this experiment, allows uniform application force, with less interference of tensile forces (20-22).

For KHN the null hypothesis tested was accepted, as well as there was no difference in micro hardness of dual resin cement between the different posts and control at different depths.

In another study (15), it was also found similar and uniform values for the same dual cement used for us along the post space in combination with a translucent fiber post.

The results for BS don't show statistical differences between thirds of the posts individually. However, between posts for the three thirds pooled the values show statistical differences. These differences may be related to the post adaptation and not to the light transmission. The T1 group, which obtained the highest values, was the only preparation of the root canal, which was shaped with the drill that came with the post. Regarding the results of comparative analysis between the different post-thirds of the high values obtained by the CT and TM Reforpost Carbon Fiber, it can be explained by the adaptation of this post, which has a cylindrical geometry like the drill used in the wide format of the root space. This hypothesis is supported by the data obtained from KHN, in which the control group was similar to others, and BS comparison between the thirds of a same post show that the clinical success in the fixation of fiber posts is probably due to the predominance of frictional retention (23-24).

The choice of self-etching cement was based on the fact that it does not use adhesive systems, eliminating this variable. However, the mechanism of chemical reaction of cement, depends not only on light energy, but also on the presence of dentin (15,25). Evaluations of KHN specimens were made without the presence of dentine, therefore, allowed evaluating only the effect of light transmission, aim of this study.

Recently, a study (26) showed that the effectiveness of LI along the fiber posts has decreased exponentially, Lambert Beer Law, with insufficient polymerization of the dual cement around the post in the apical region. These and other authors (27-28), using posts 10mm in height. Considering the principles governing the placement of posts, this height seems to be less than ideal. However, the short-post test results indicate a decrease or insufficiency to conduct light, especially in the deeper regions (26-30).

The results of this study led to the following conclusions:

- For the cement used, the amount of light transmitted through the post did not influence the KNH nor the BS significantly, among the different posts and thirds evaluated.

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5.1 Pinos utilizados e altura padrão

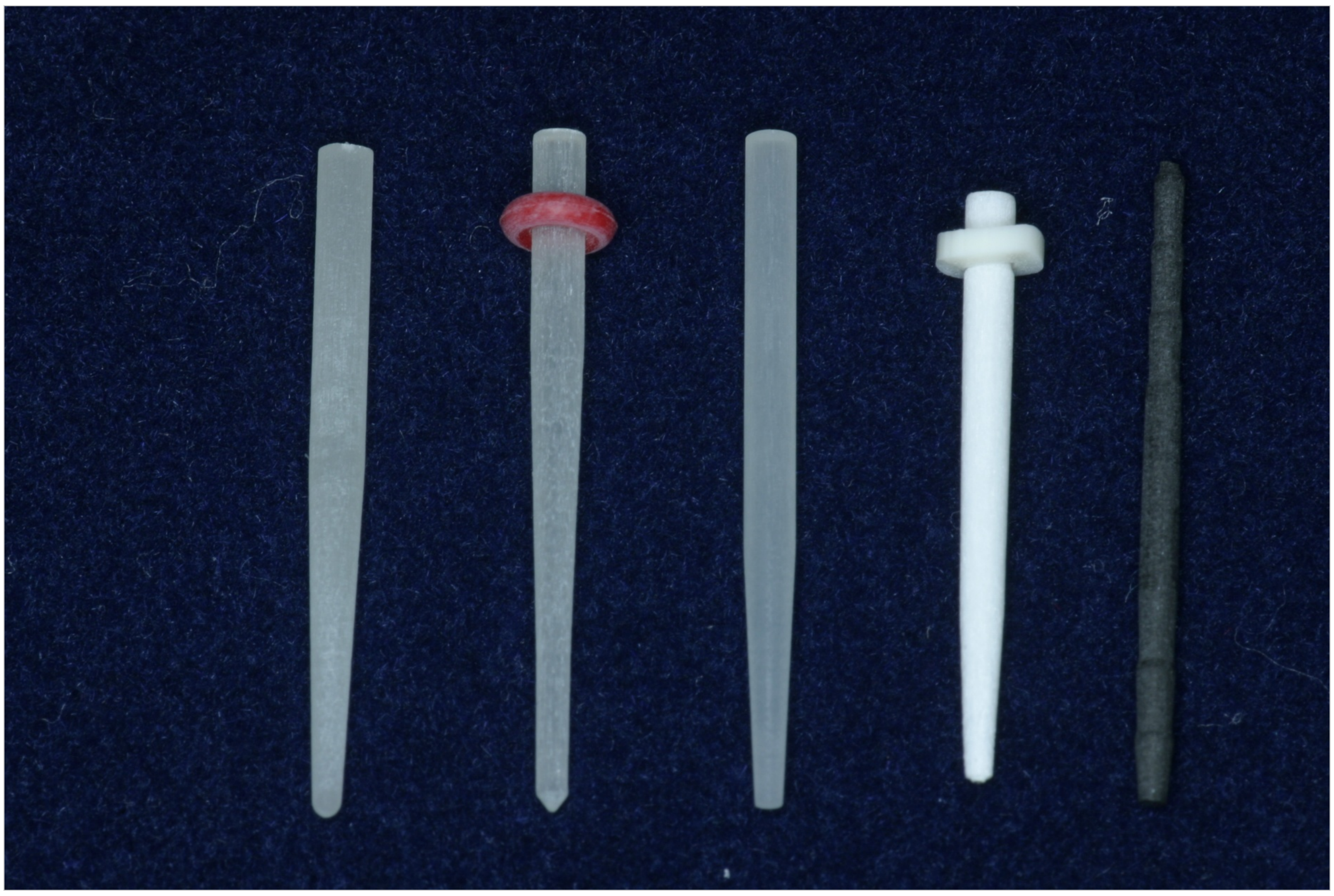


Fig. 1. Pinos utilizados neste estudo. White Post DC, DT Light Post, FRC Postec Plus, Exacto e Reforpost Fibra de Carbono.

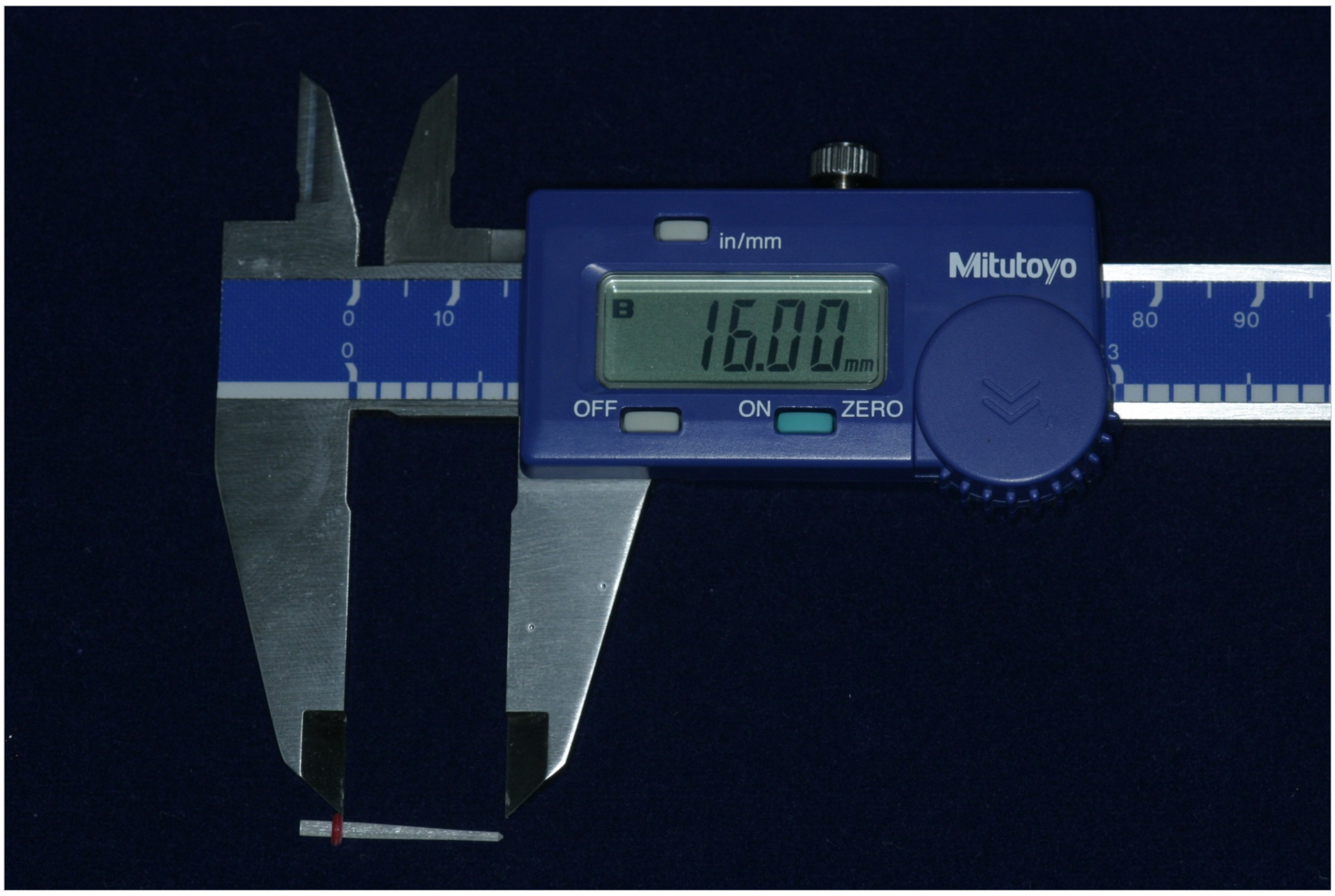


Fig. 2. Paquímetro digital determinando a altura padrão dos pinos em 16 mm.

5. 2 Figuras do artigo 1

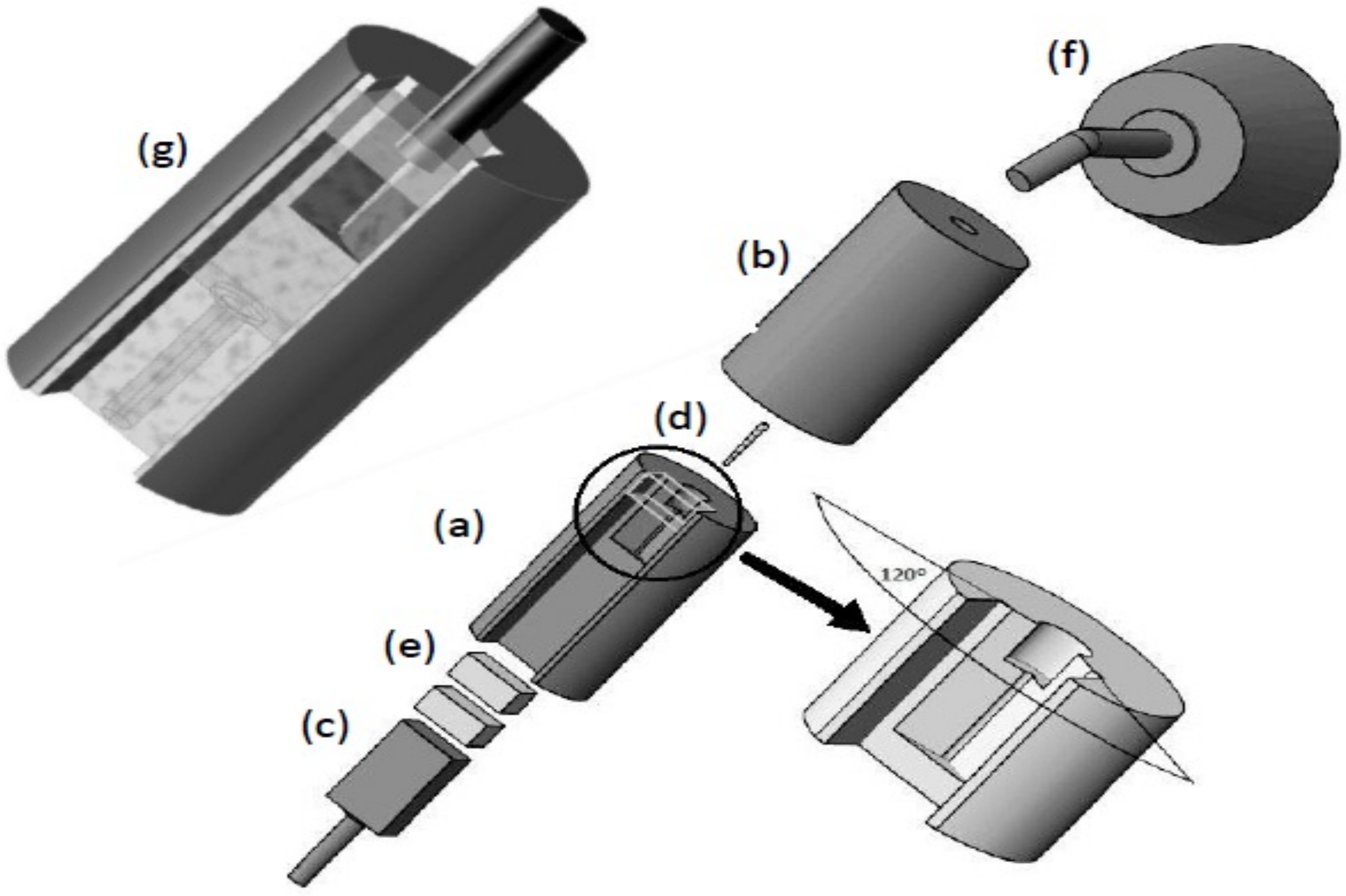


Fig. 1 (a) corpo da matriz que aloja os pinos, o medidor de potência digital e de um a três blocos metálicos dependendo do terço a ser avaliado; (b) cilindro externo que aloja as outras outras partes descritas e a ponta do aparelho fotopolimerizador; (c) Sensor do medidor de potência digital; (d) pino; (e) blocos metálicos que determinam o terço a ser medido; (f) ponta do aparelho fotopolimerizador; (g) Conjunto montado em posição para as avaliações.

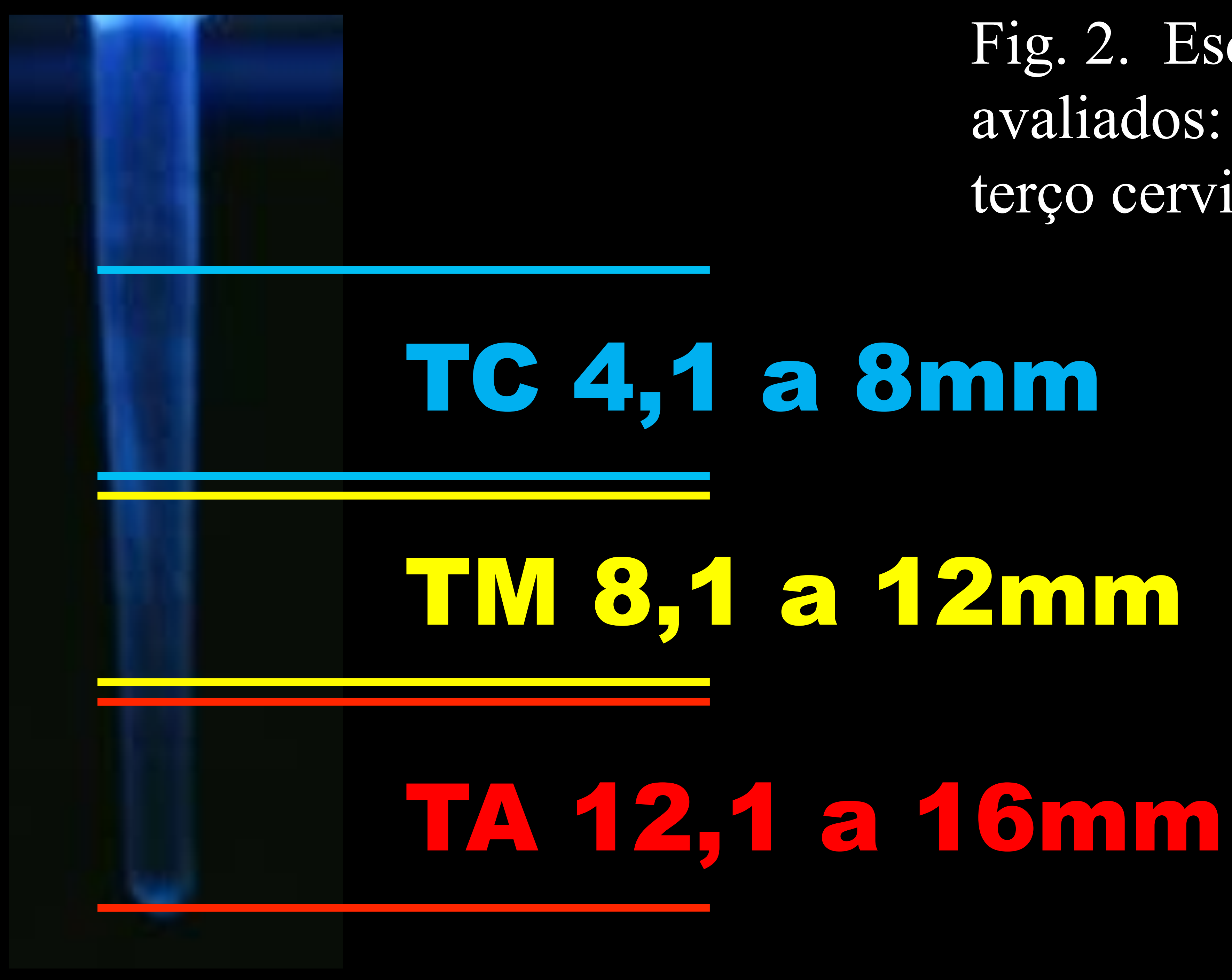


Fig. 2. Esquema da divisão dos espaços dos pinos avaliados: TA, terço apical; TM, terço médio; TC, terço cervical.

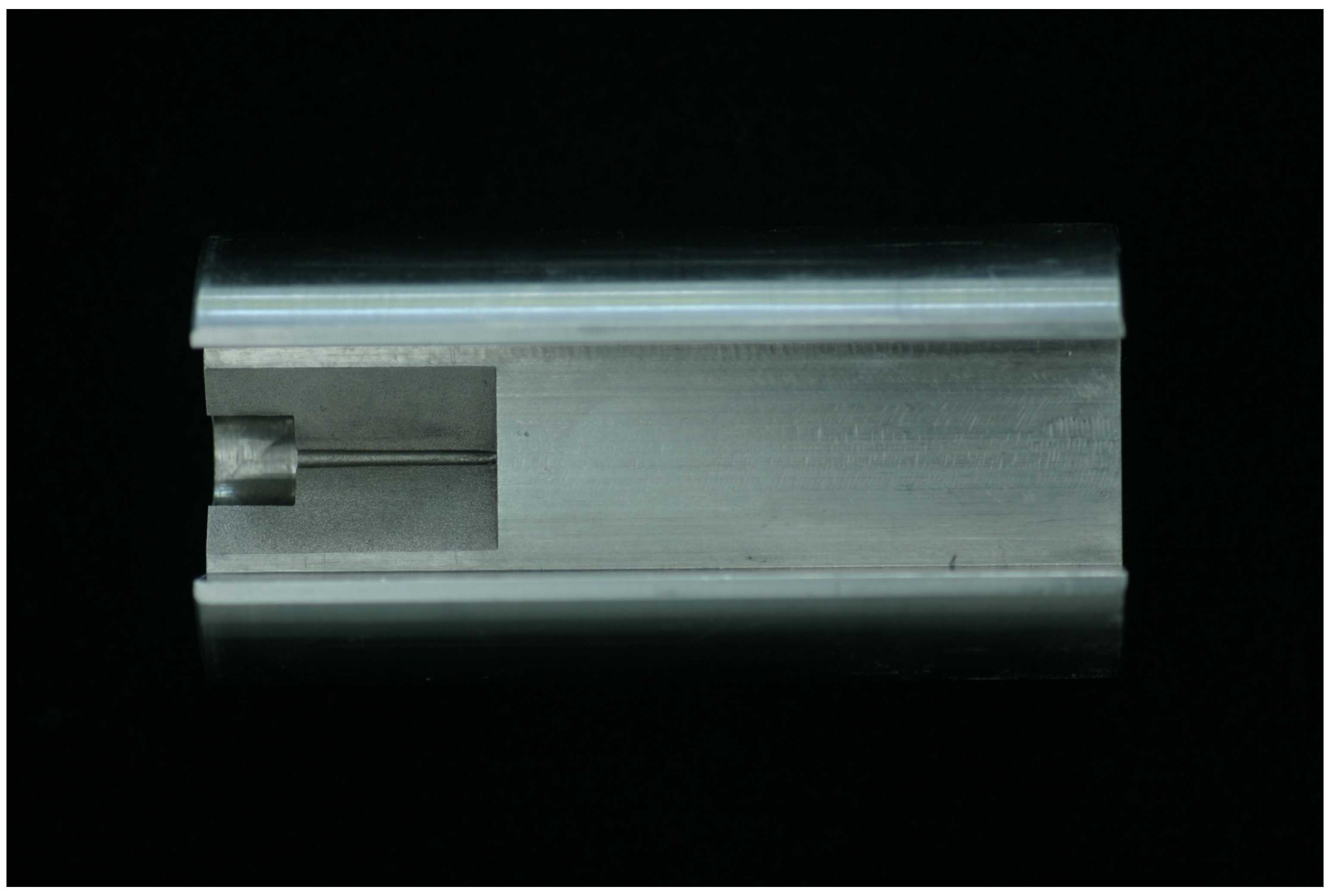


Fig. 3. Corpo da matriz metálica (C).

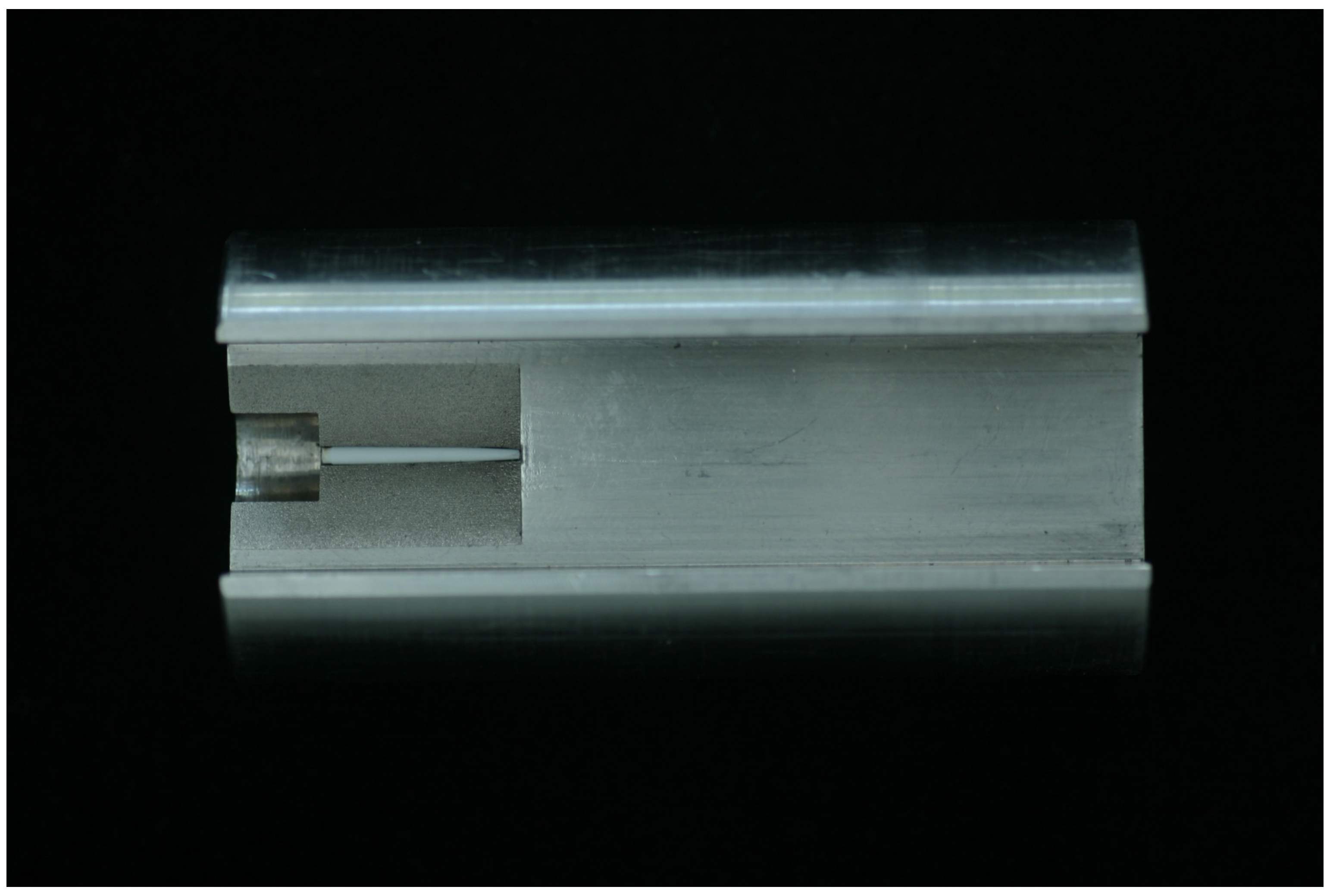


Fig. 4. Corpo da matriz metálica (C) com o seu respectivo pino (D) em posição.

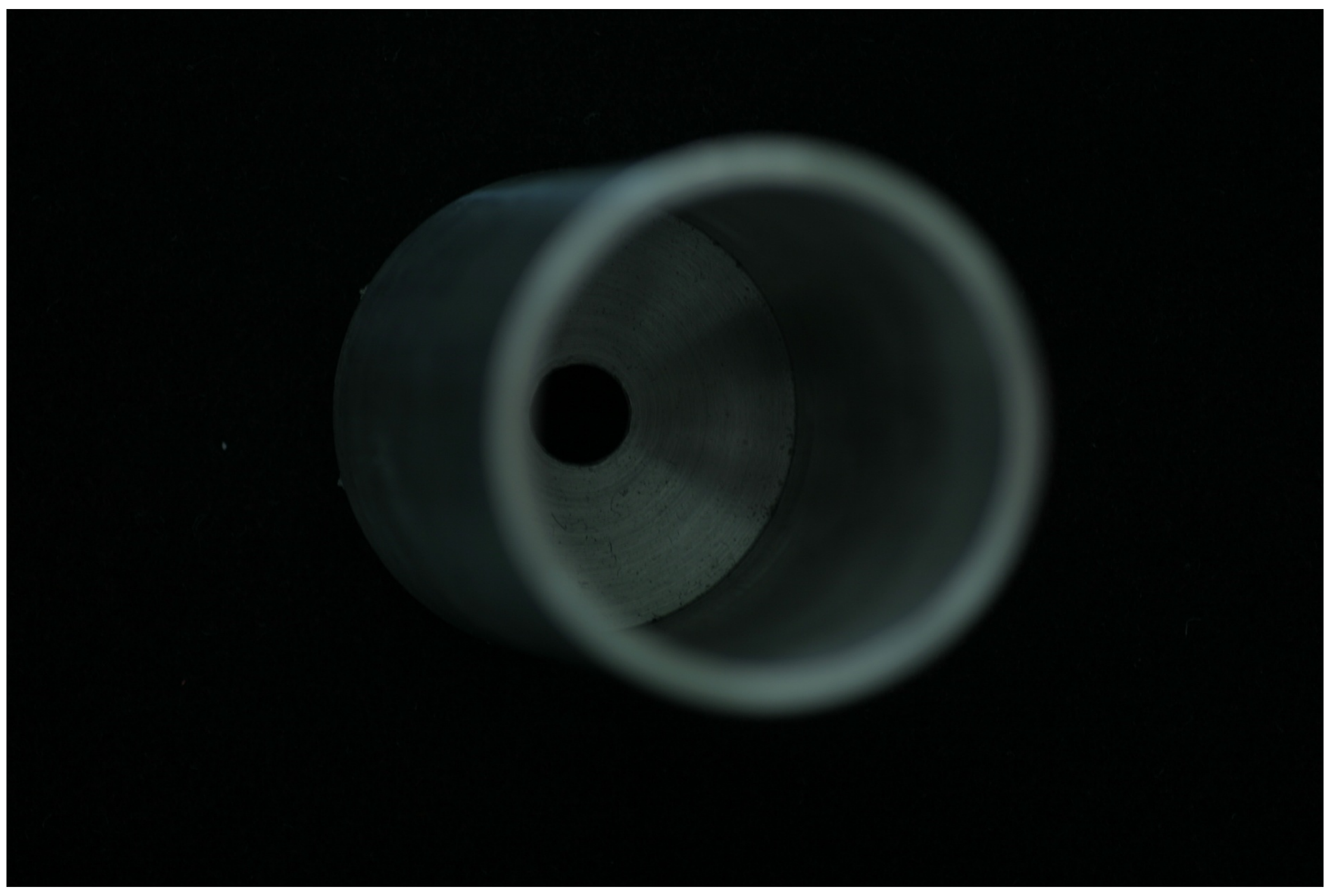


Fig. 5. Cilindro externo da matriz metálica (E), vista da face interna.

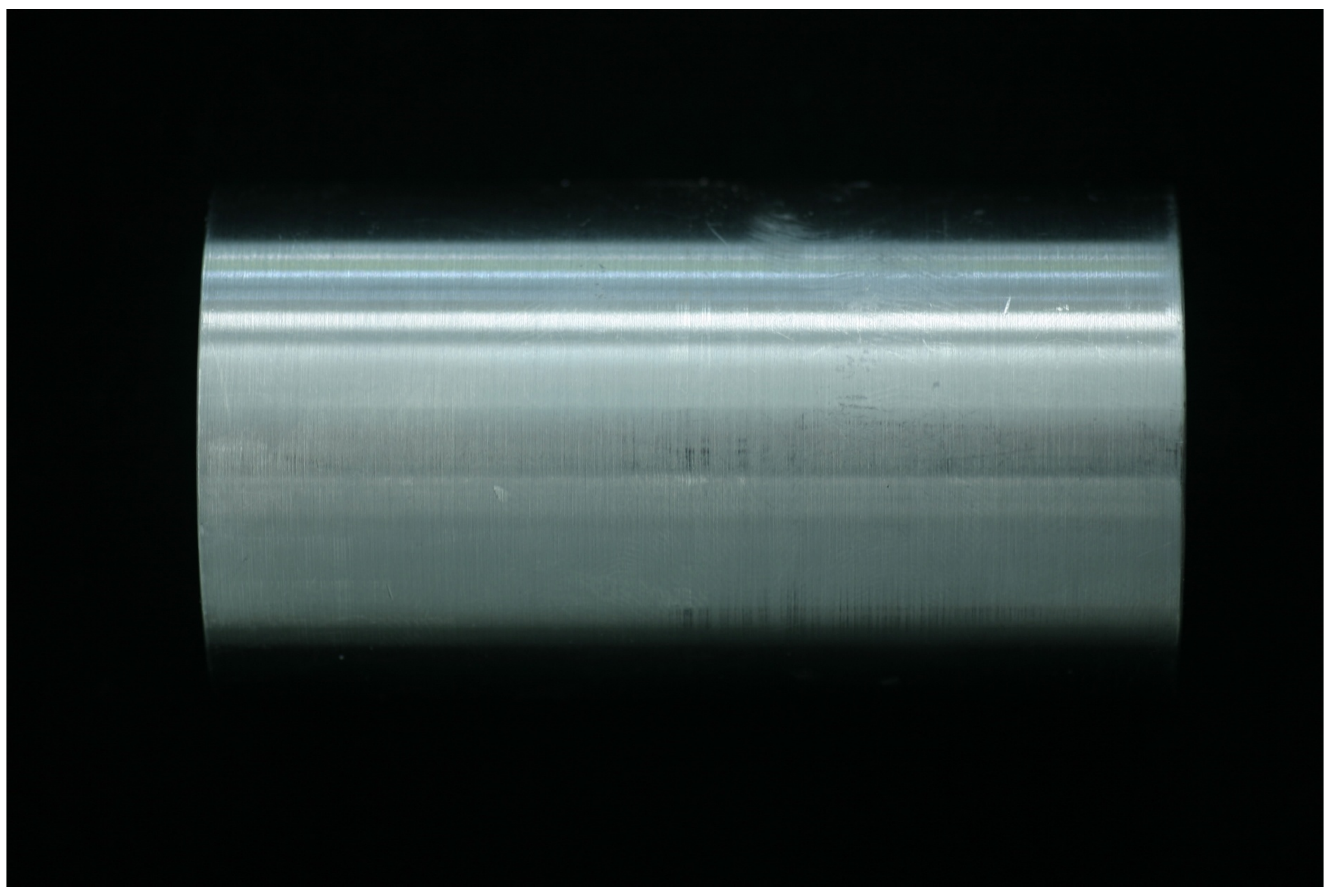


Fig. 6. Cilíndro externo da matriz metálica (E) , vista lateral.

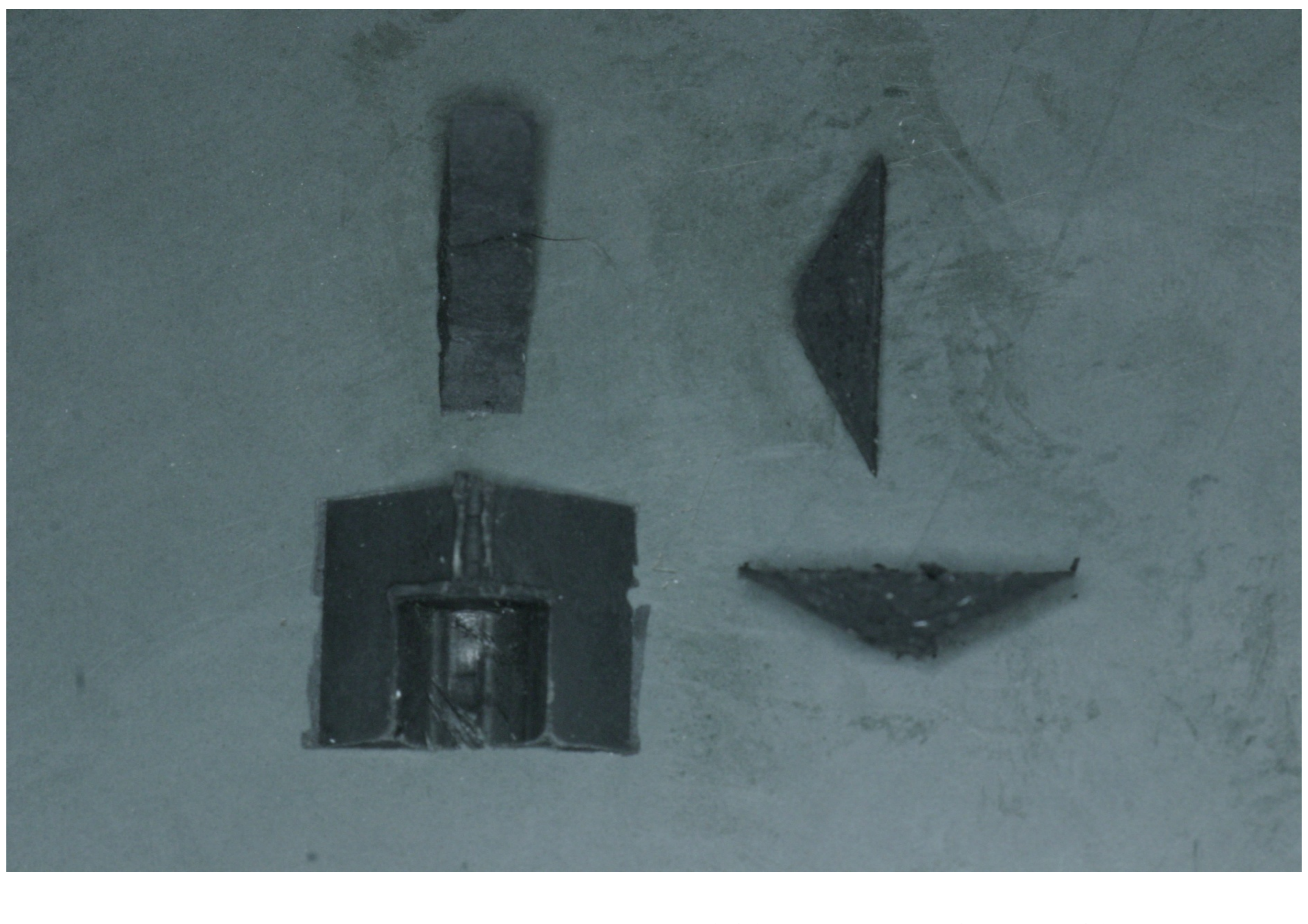


Fig. 7. Estruturas em silicone de adição e corante preto que auxiliam a determinar o terço a ser medido bem como isolamneto de fontes de luz externas.

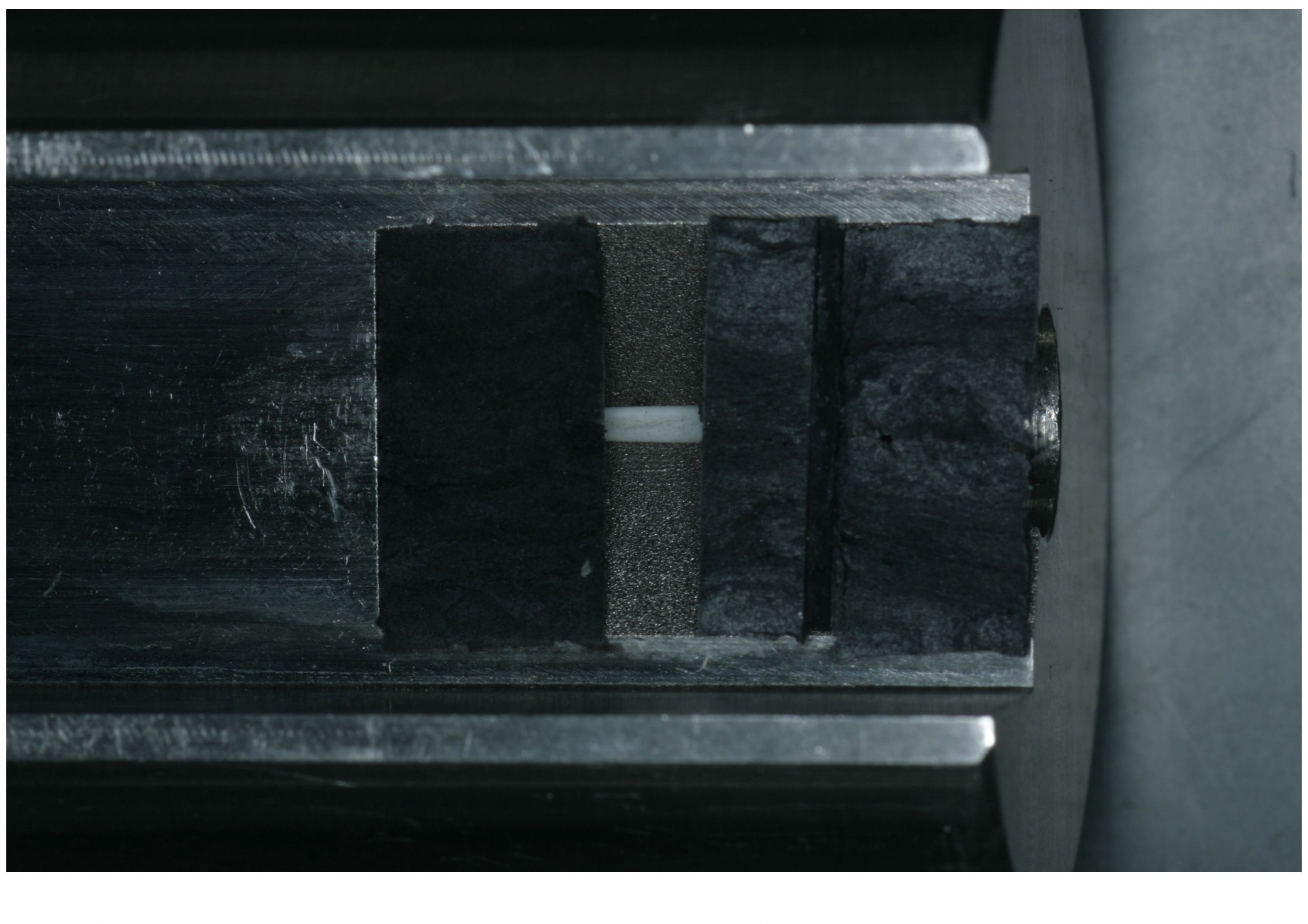


Fig. 8. Estruturas em silicone posicionadas de modo a expor a região de TC ao sensor digital.

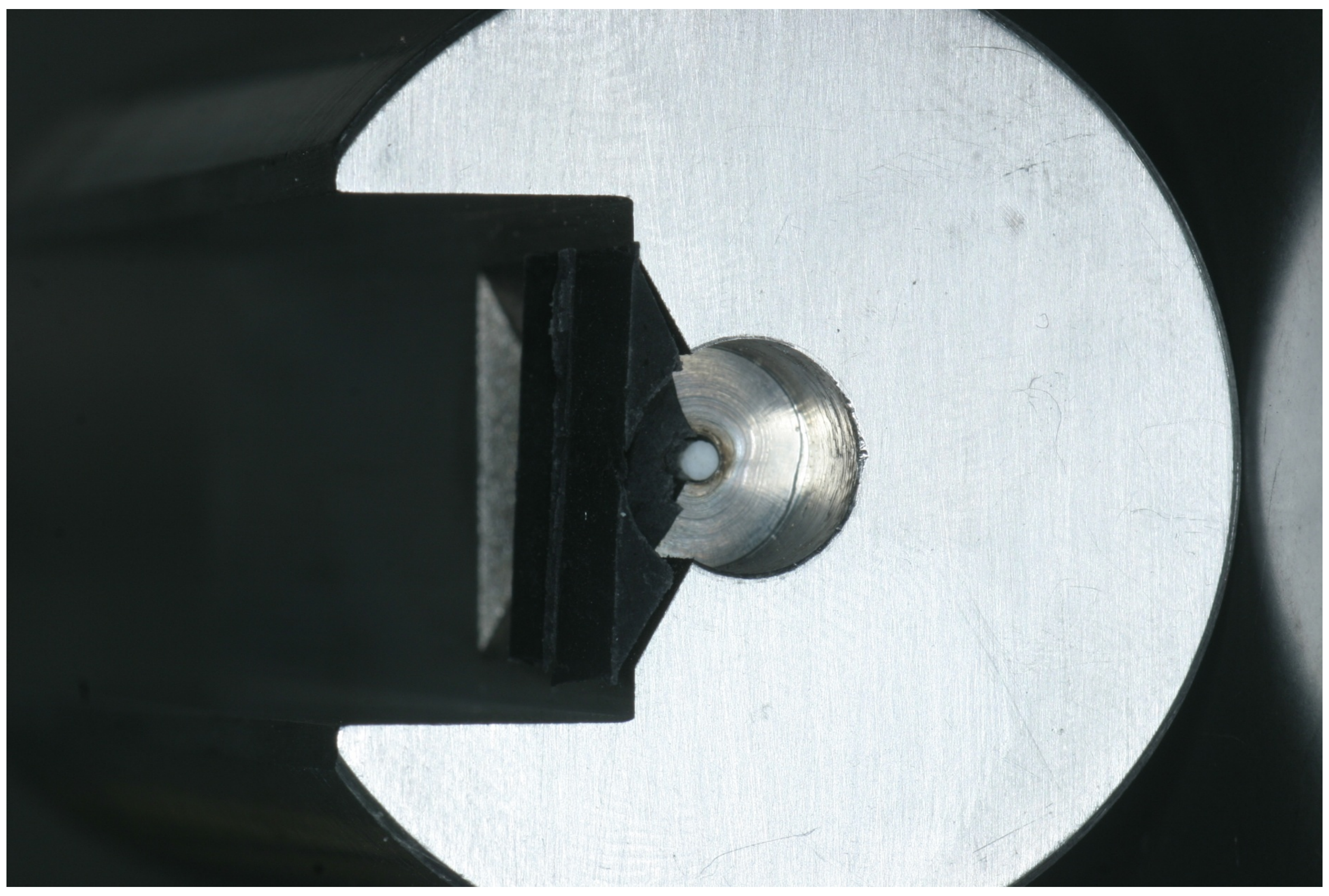


Fig. 9. Pormenor do corpo da matriz (C) com a estrutura em silicone justaposta ao pino (D).

Fig. 10. Blocos metálicos (B).

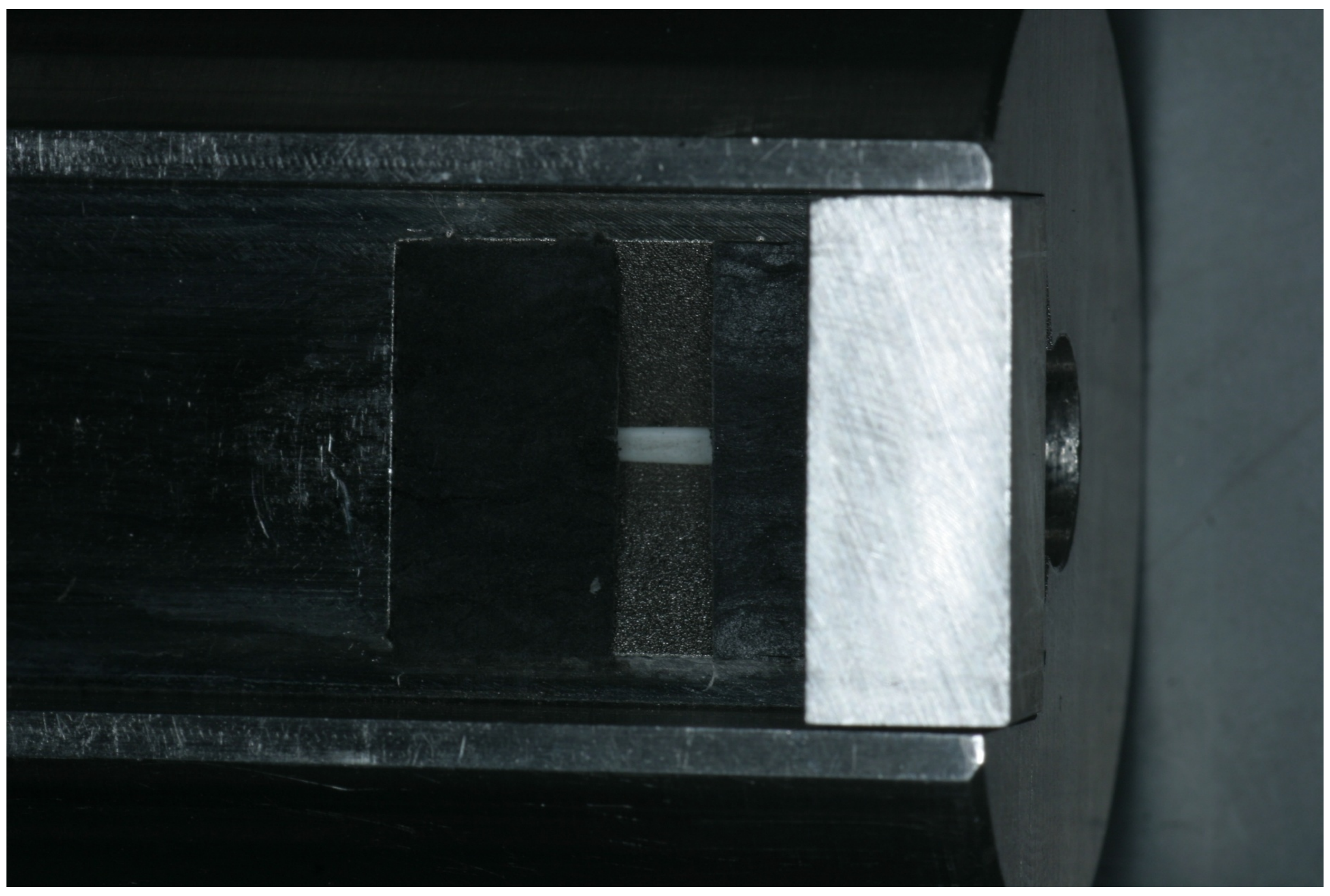


Fig. 11. Estruturas em silicone e bloco metálico (B) posicionado no corpo da matriz (C) de modo a avaliar o TC …

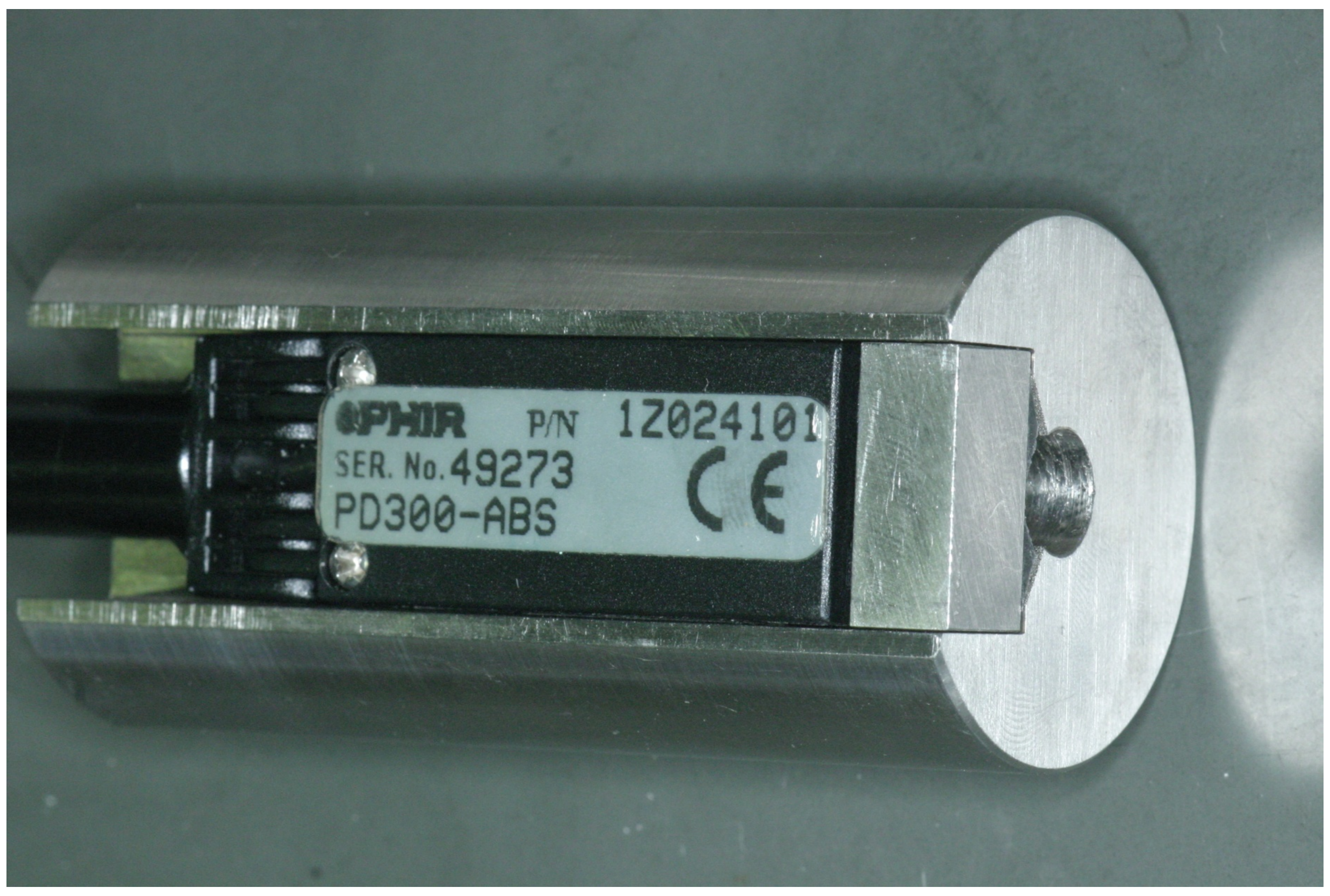


Fig. 12 … e com o sensor medidor de potência (A).

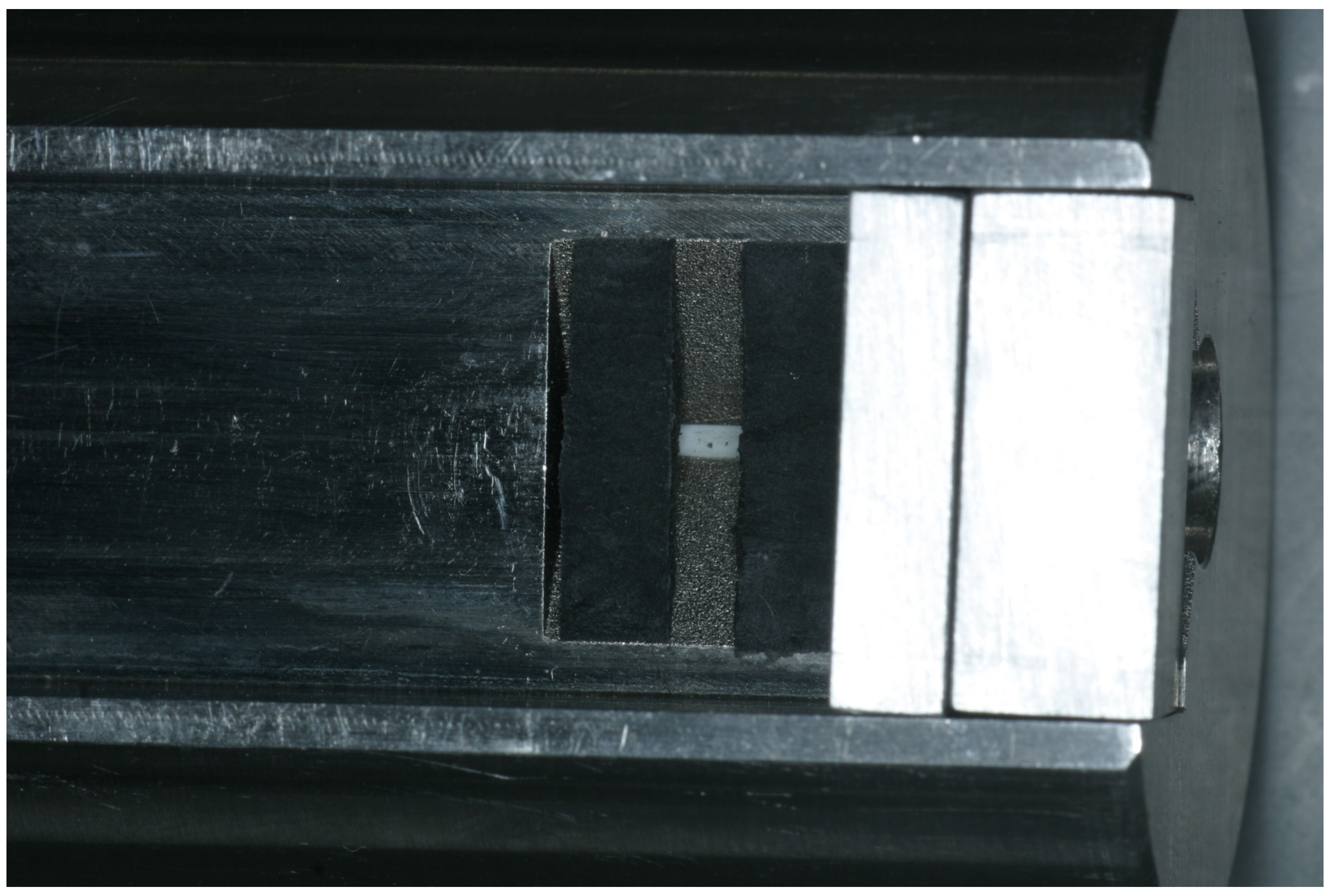


Fig. 13. Estruturas em silicone e 2 blocos metálicos (B) posicionados no corpo da matriz (C) de modo a avaliar o TM …

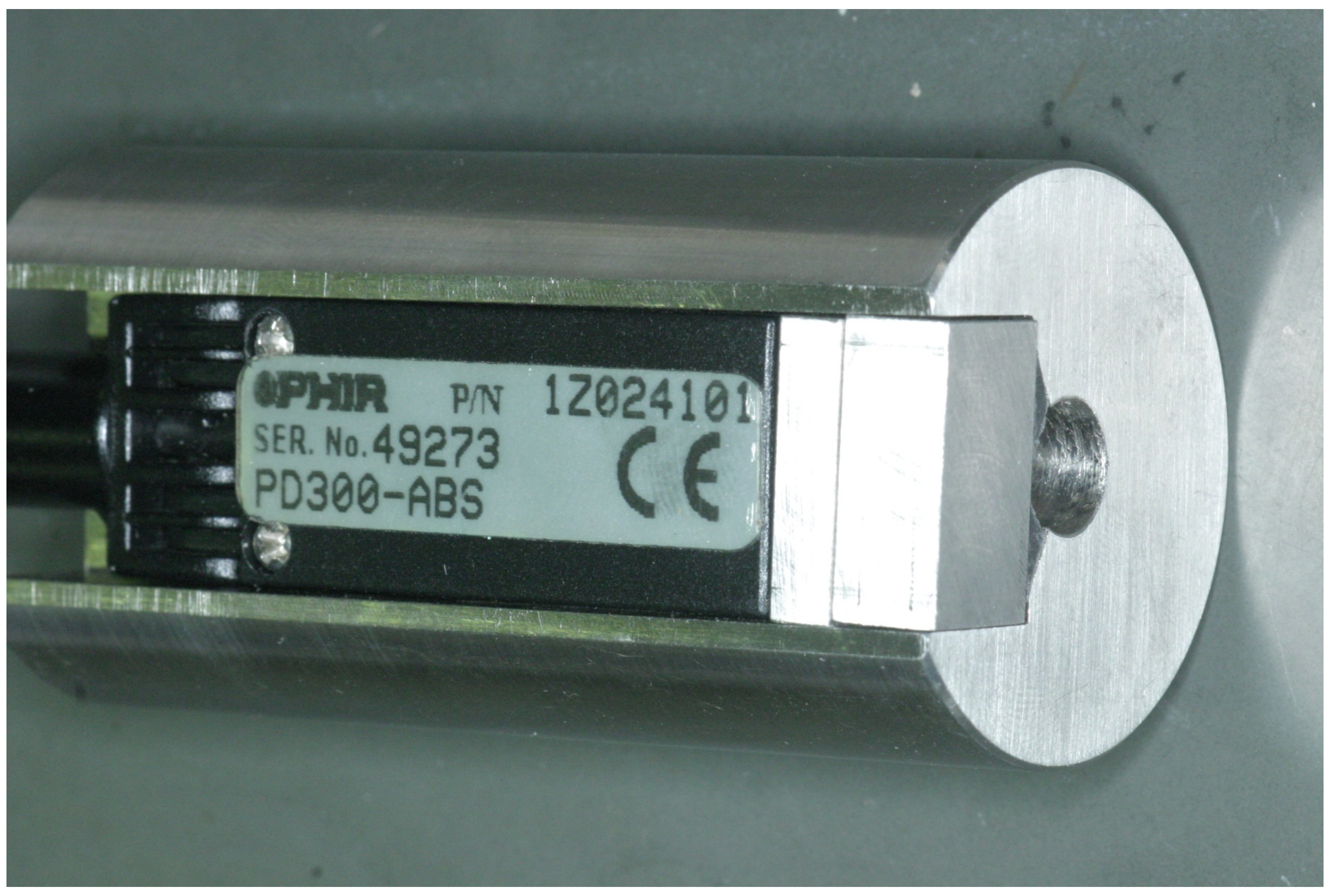


Fig. 14 … e com o sensor medidor de potência (A).

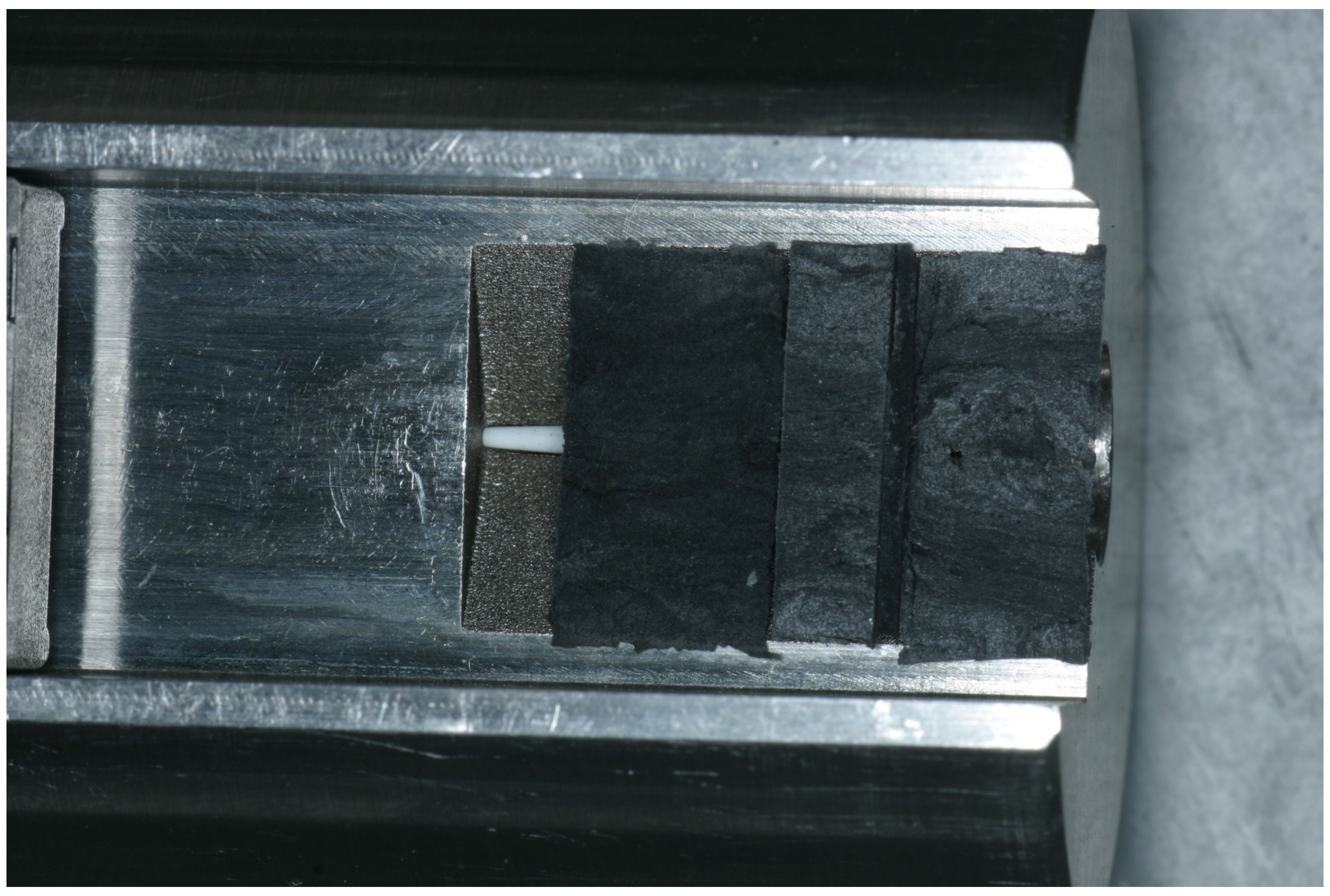


Fig. 15. Estruturas em silicone posicionados no corpo da matriz (C) de modo a avaliar o TA …

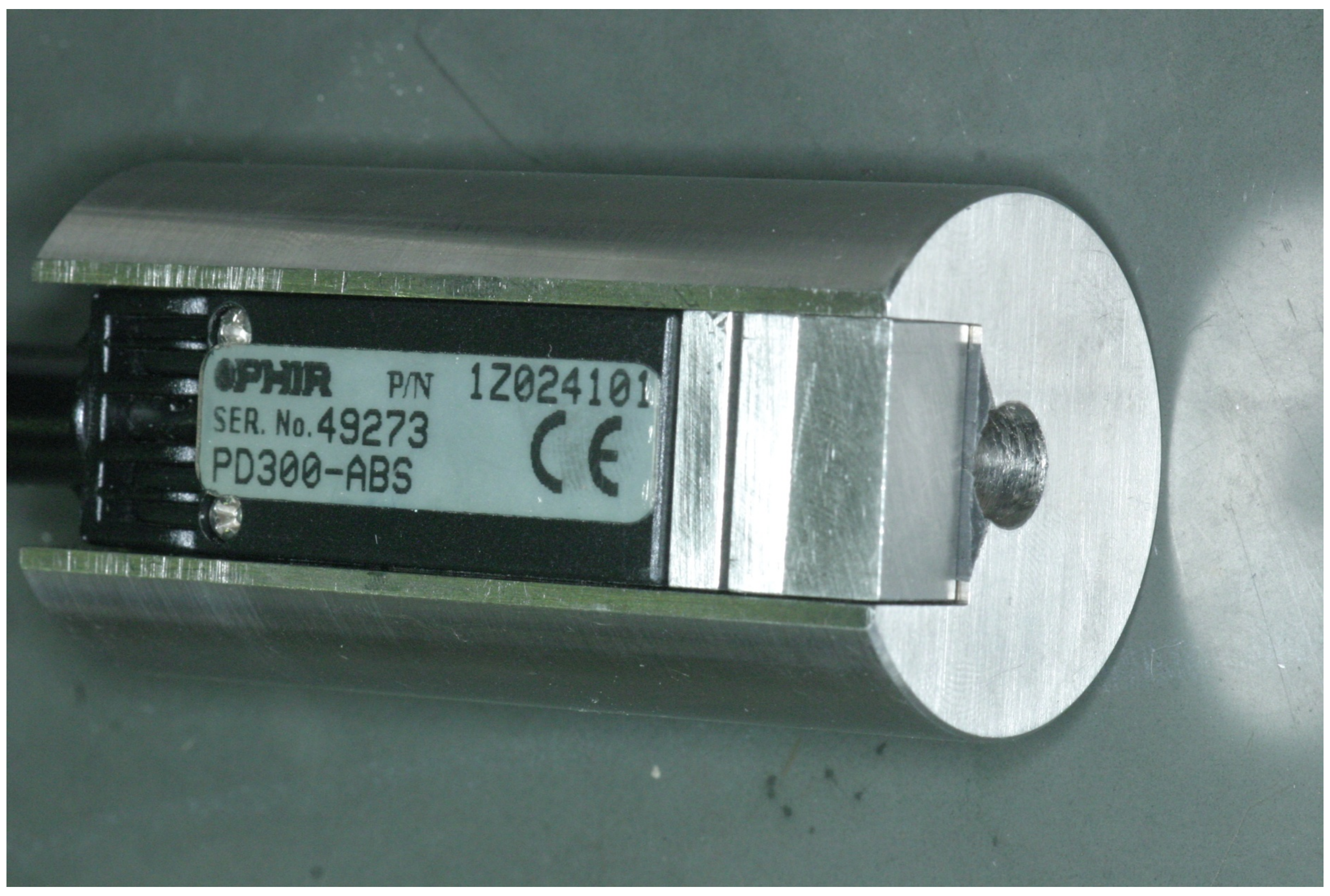


Fig 16 … e com os blocos metálicos (B) e o sensor medidor de potência (A).

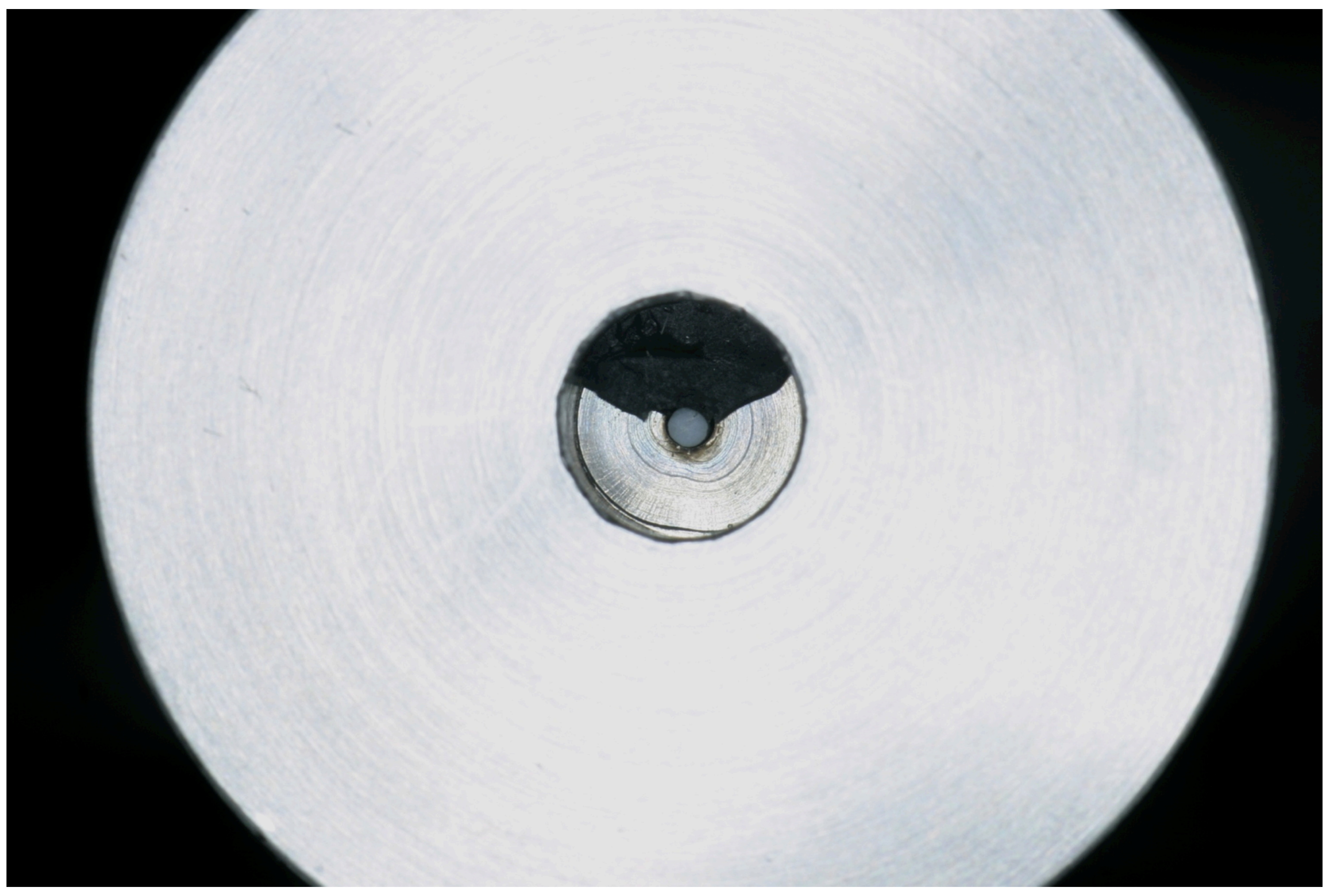


Fig. 17. Conjunto de (A), (B), (C), (D) e (E) em posição para a avaliação, vista superior e …

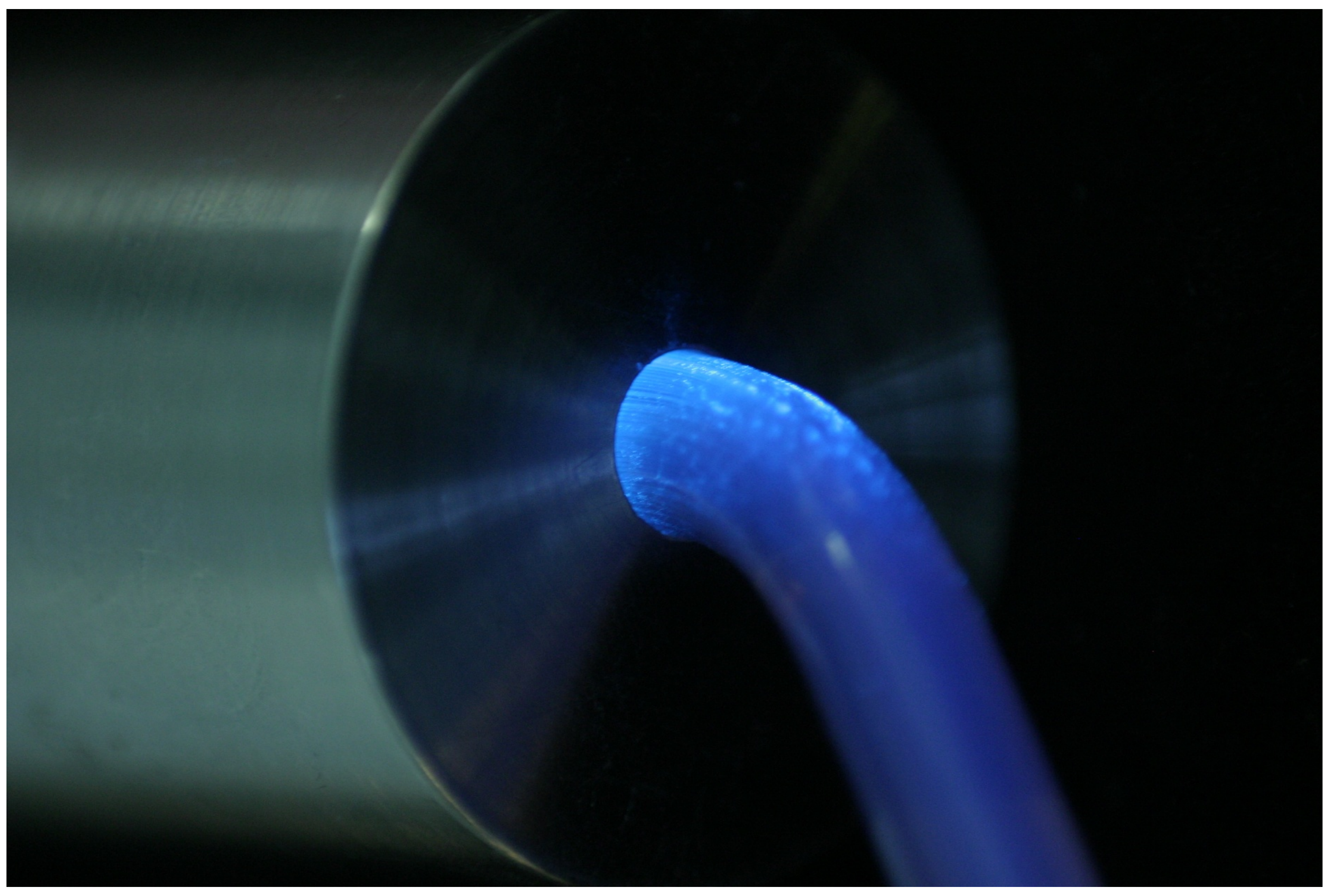


Fig. 18. … ponta do aparelho fotopolimerizador (F).

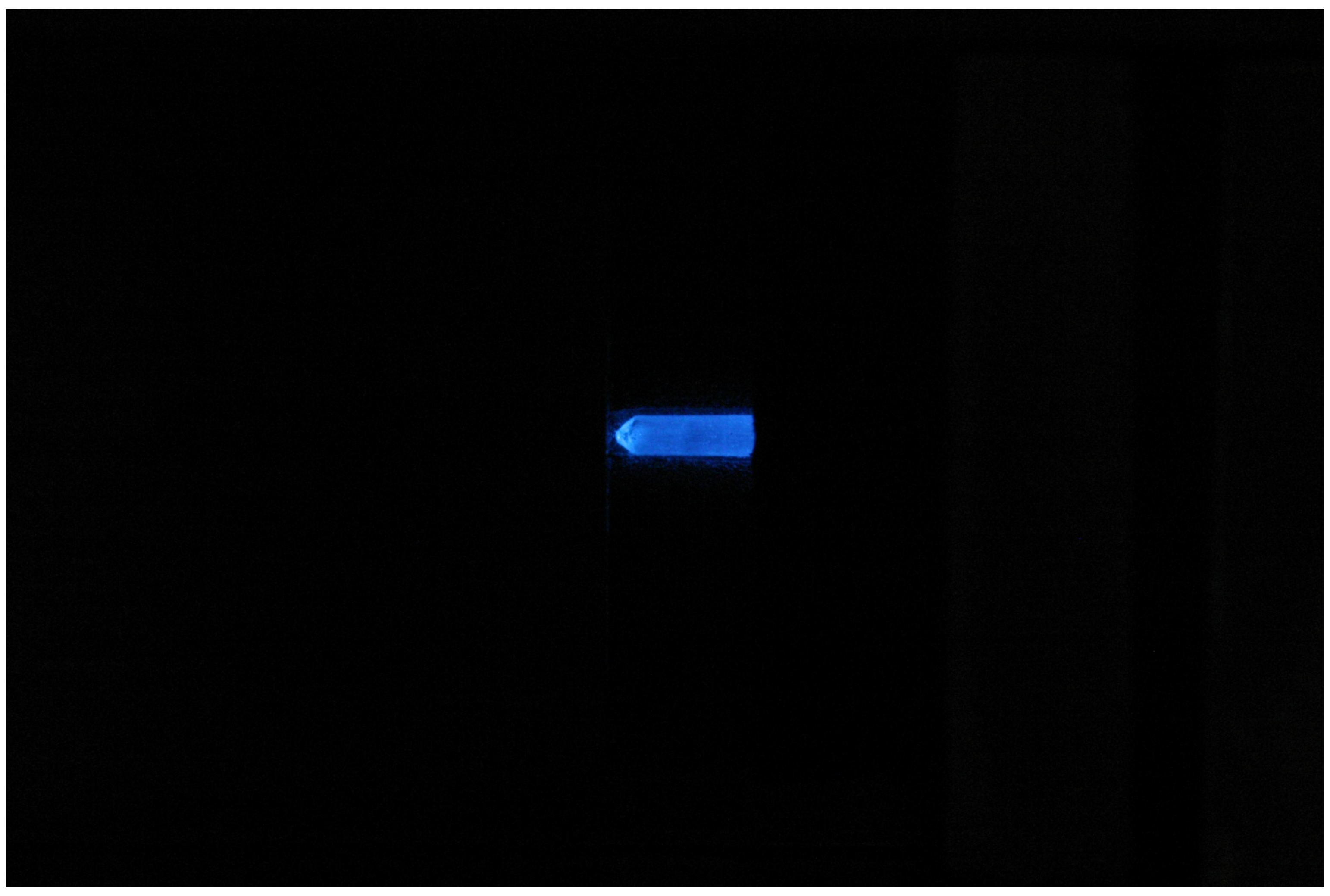


Fig. 19. Pormenor da luz visível no TA após o devido posicionamento das estrutturas em silicone.

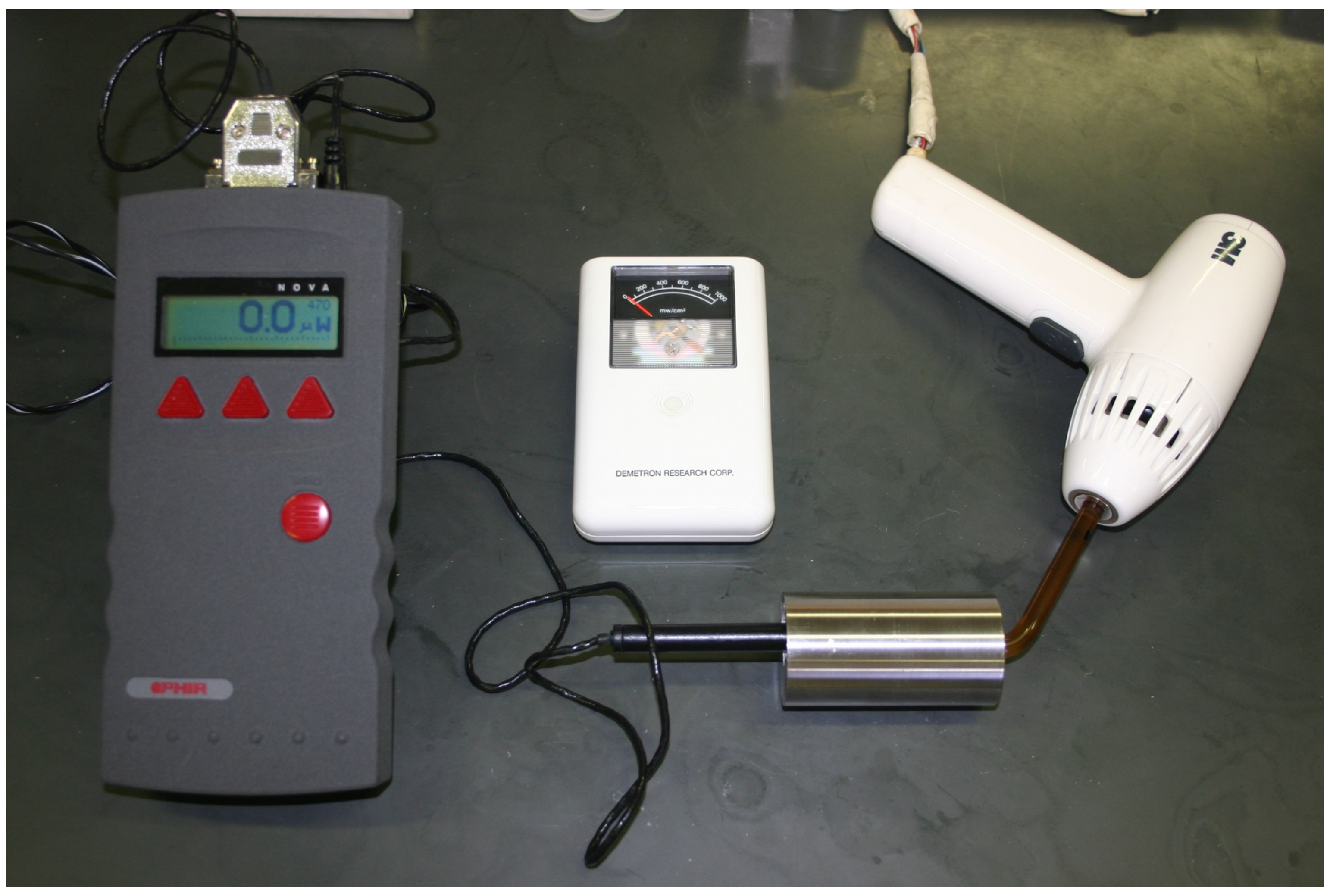


Fig. 20. Conjunto preparado para a avaliação: aparelho medidor de potência digital; radiômetro; matriz metálica e; aparellho fotopolimerizador.

5. 3A Figuras do artigo 2 - Microdureza

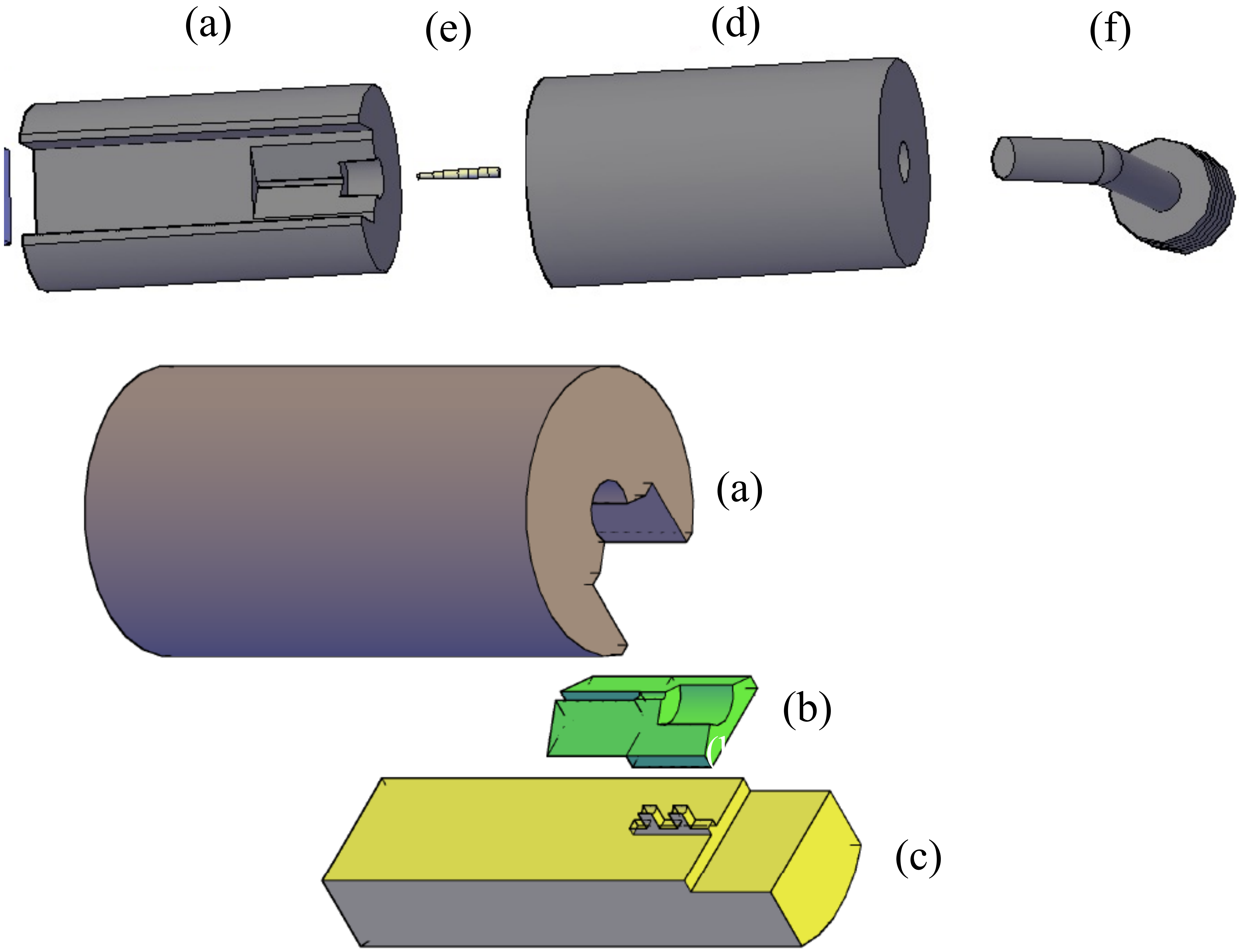


Fig. 1. Matriz metálica: (a) corpo da matriz que aloja os pinos; (b) estrura que contém o cimento resinoso durante a polimerização; (c) estrutura que divide o cimento resinoso para dar origem aos blocos de dimensões padronizadas após a polimerização; (d) cilindro externo que aloja as outras outras partes pino e ponta do aparelho fotopolimerizador; (e) pino; (f) ponta do aparelho fotopolimerizador.

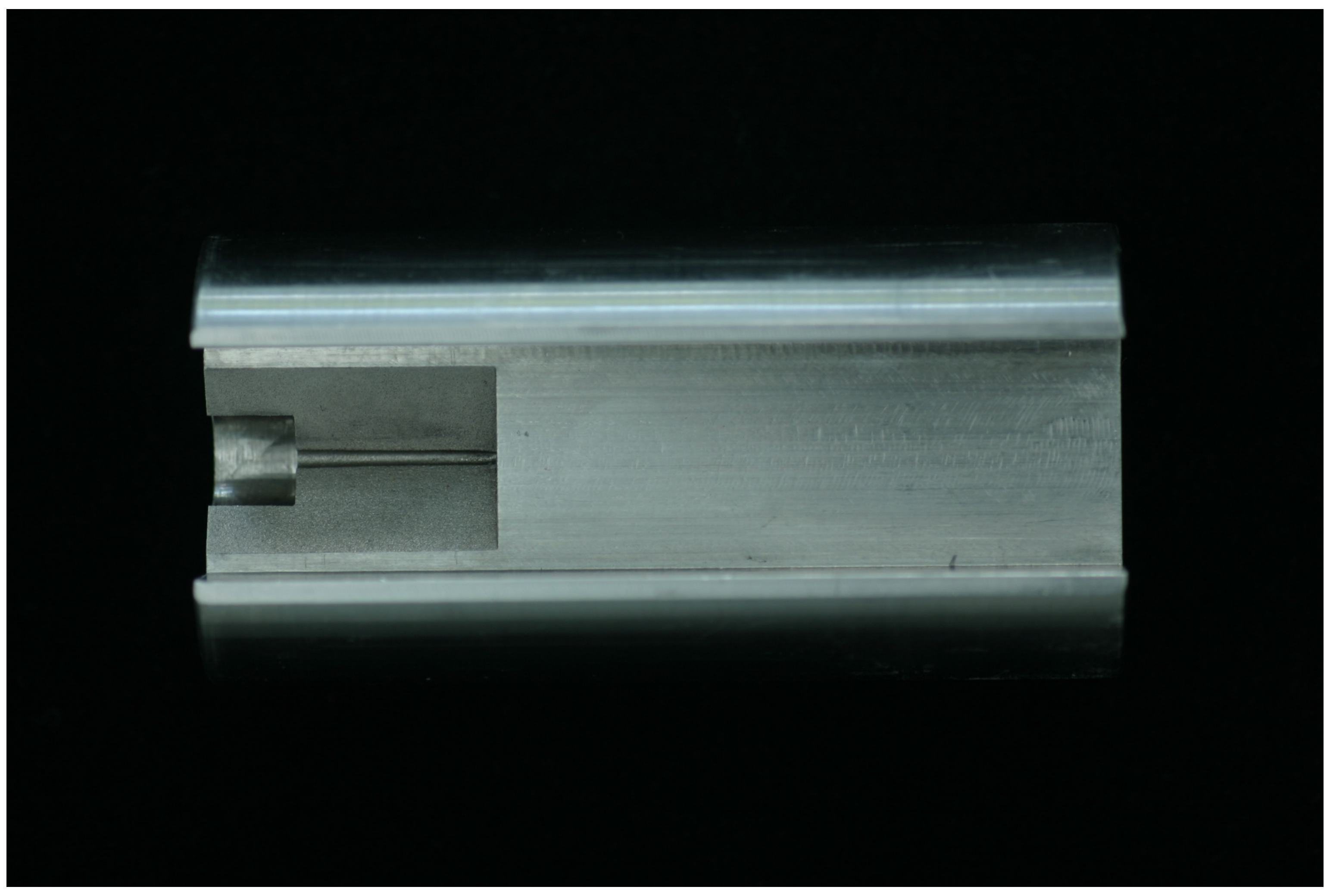


Fig. 2. Corpo da matriz metálica que aloja os pinos (a).

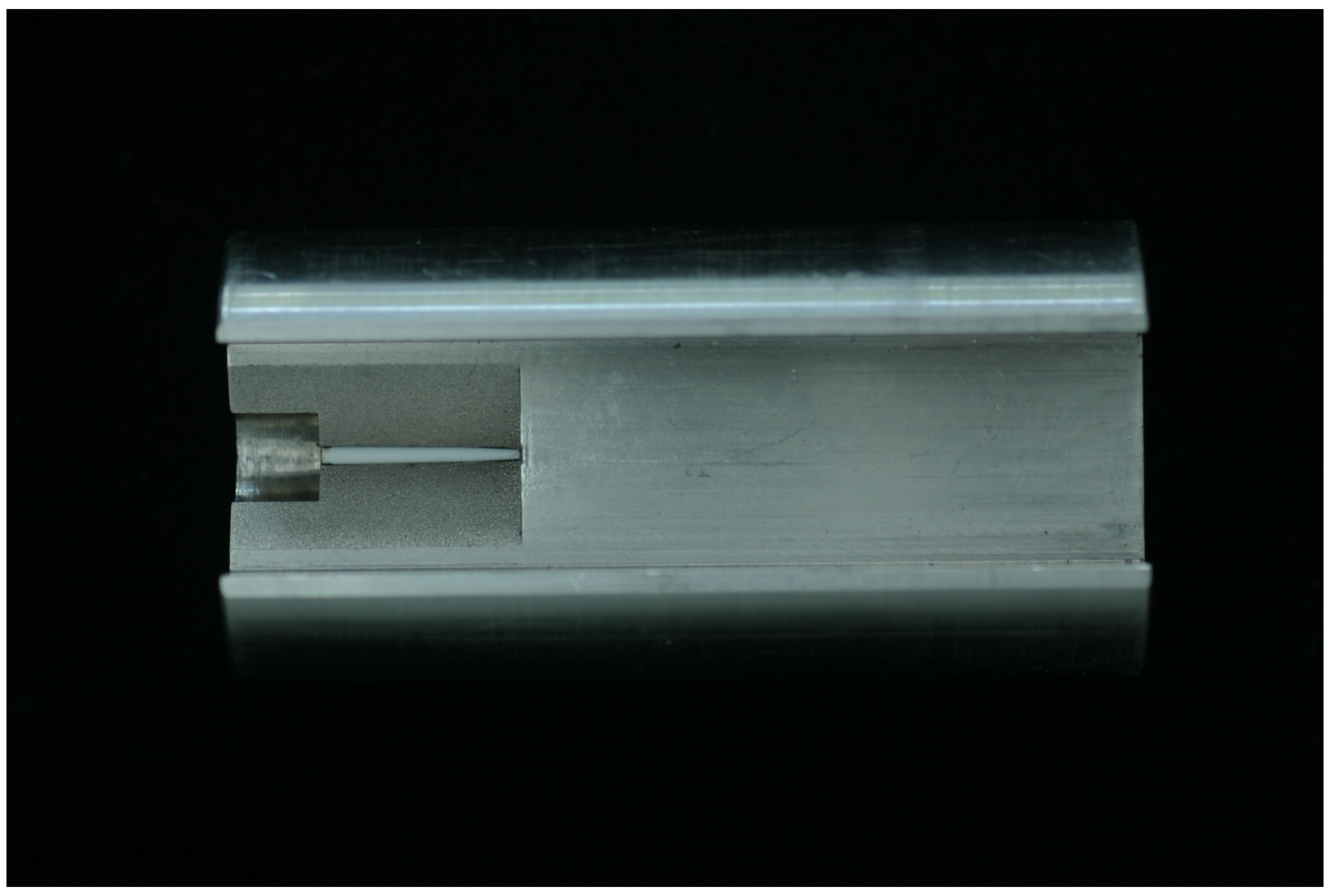


Fig. 3. Corpo da matriz metálica (a) com o seu respectivo pino em posição.

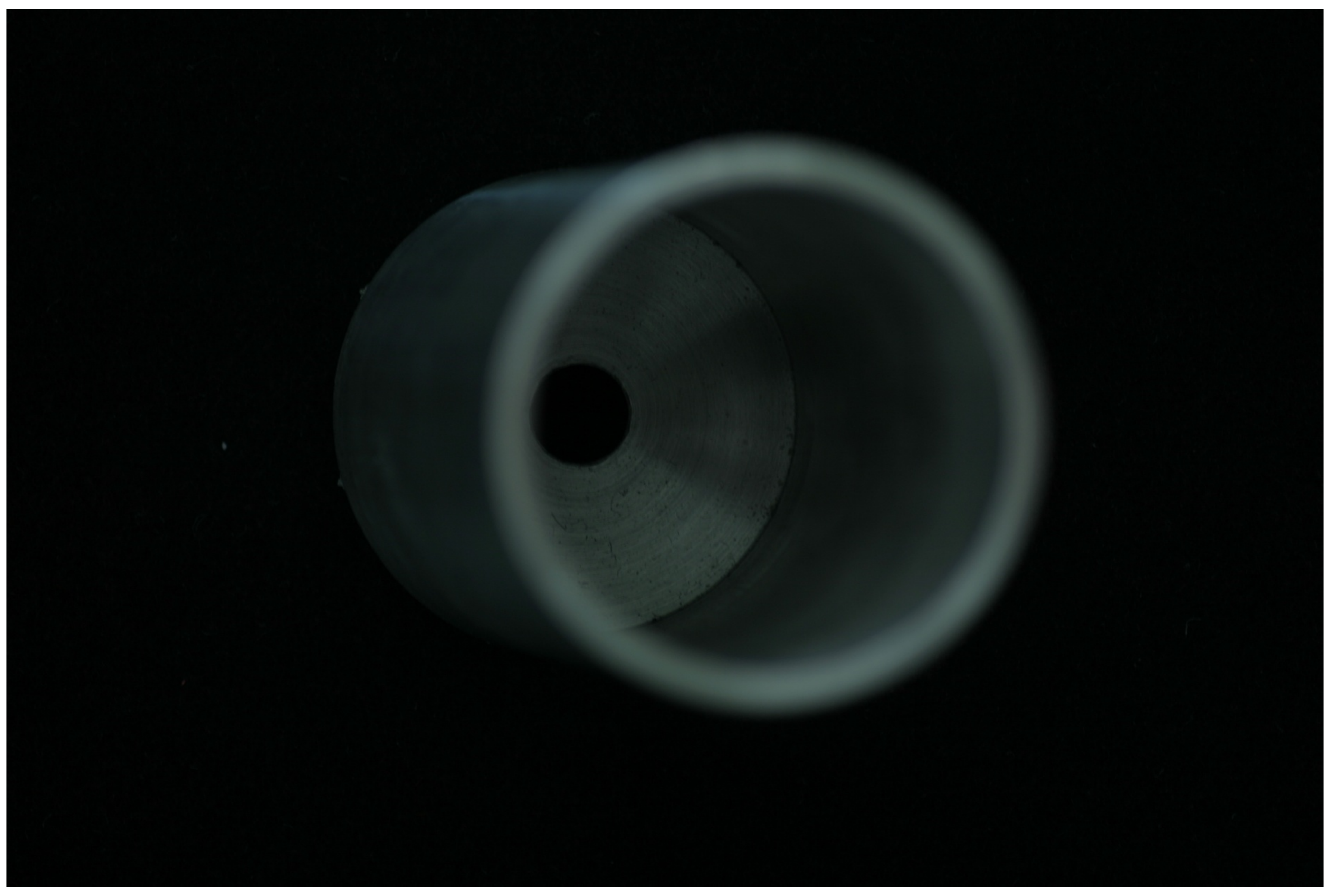


Fig. 4. Cilindro externo da matriz metálica (d), vista da face interna.

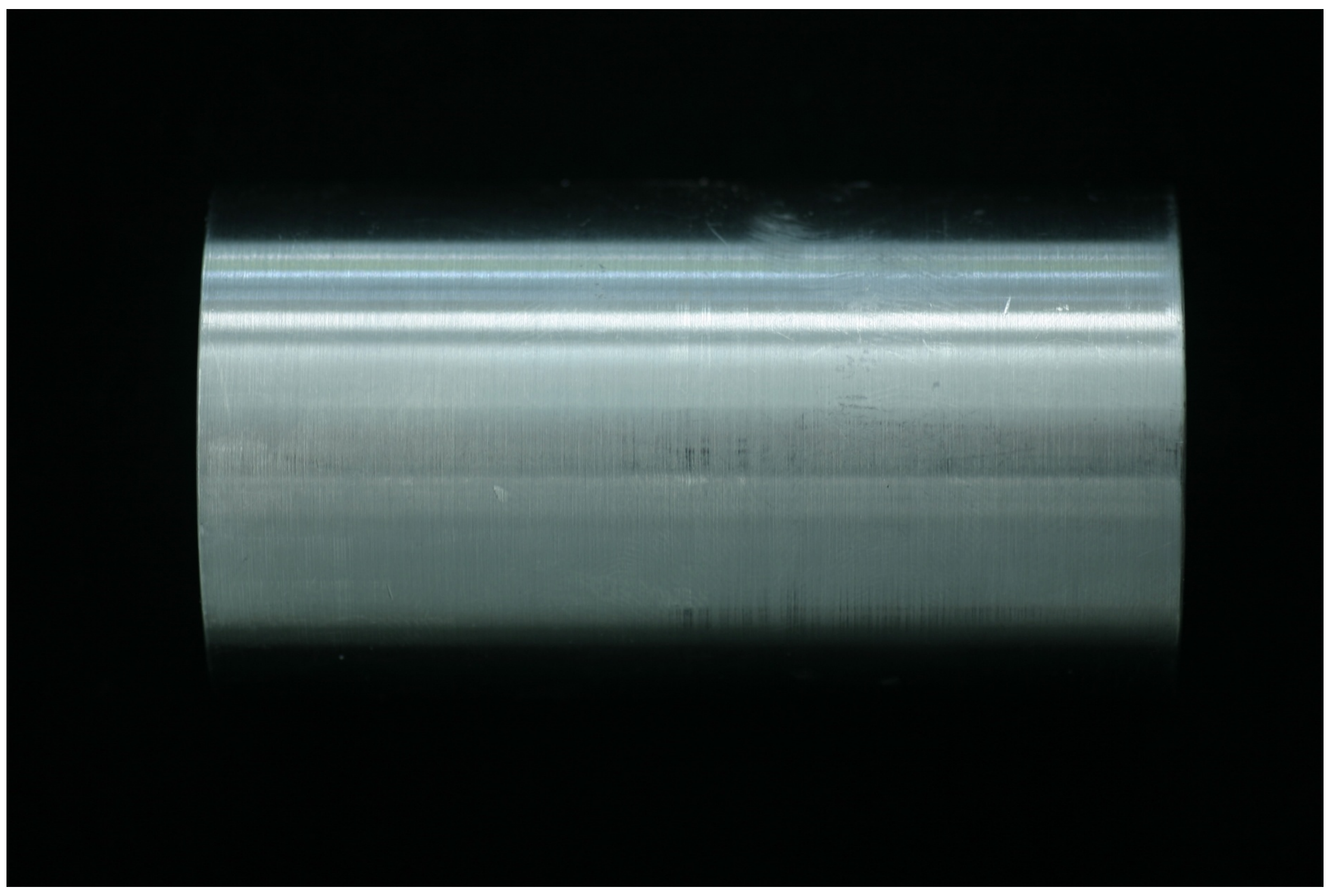


Fig. 5. Cilíndro externo da matriz metálica (d) , vista lateral.

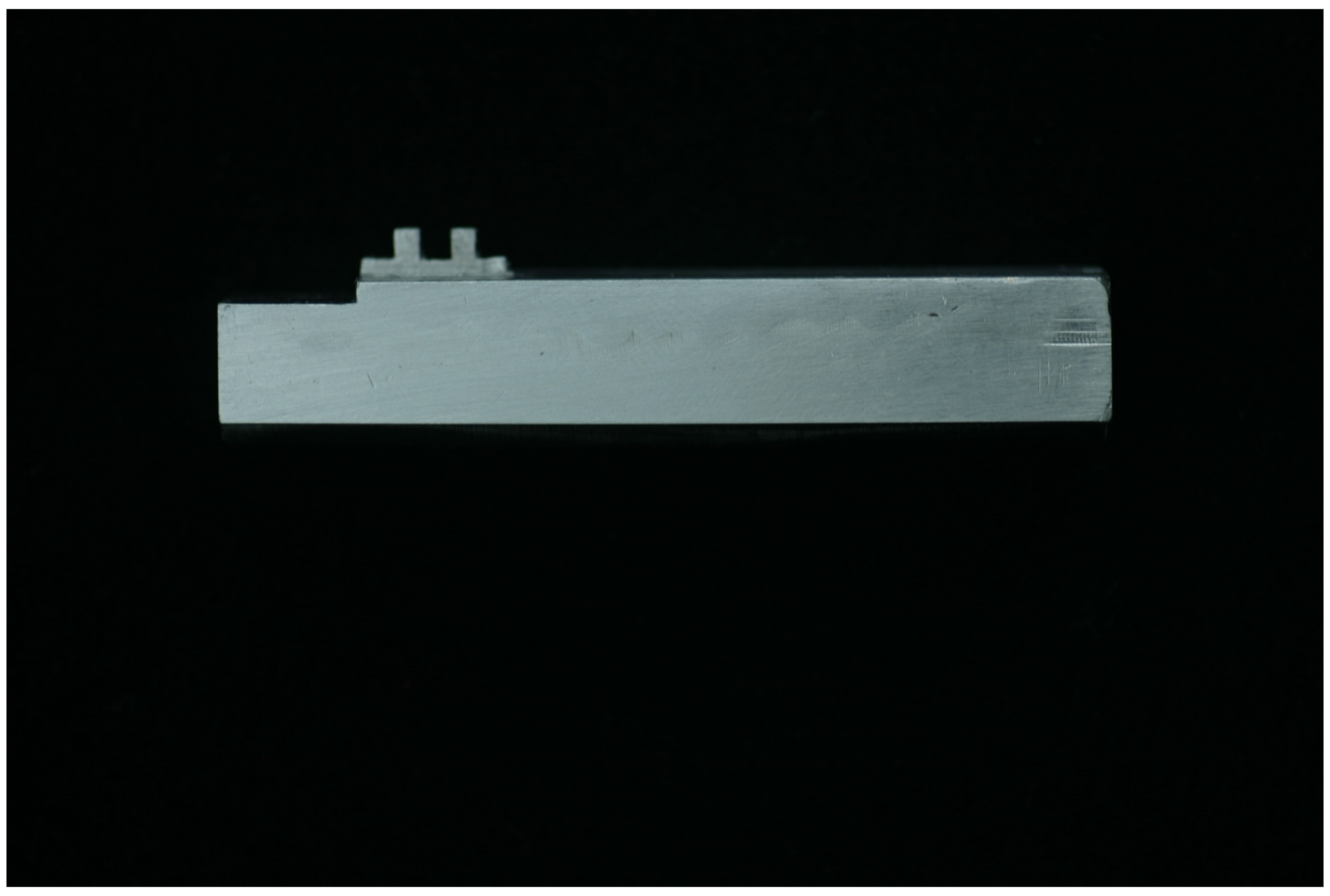


Fig. 6. Estrutura que divide o cimento em blocos de dimensões padronizadas (c), vista lateral e ...

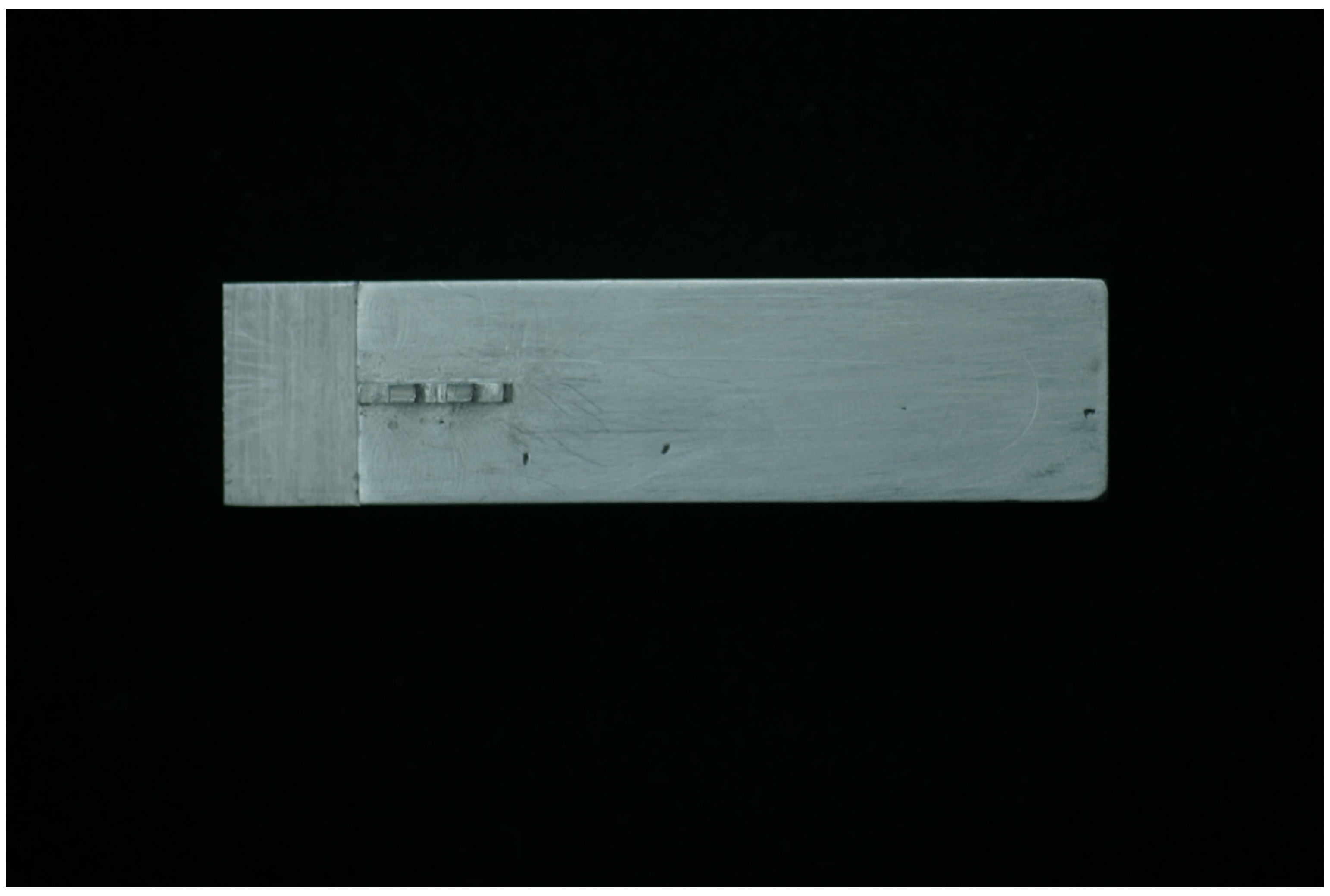


Fig. 7 …vista superior.

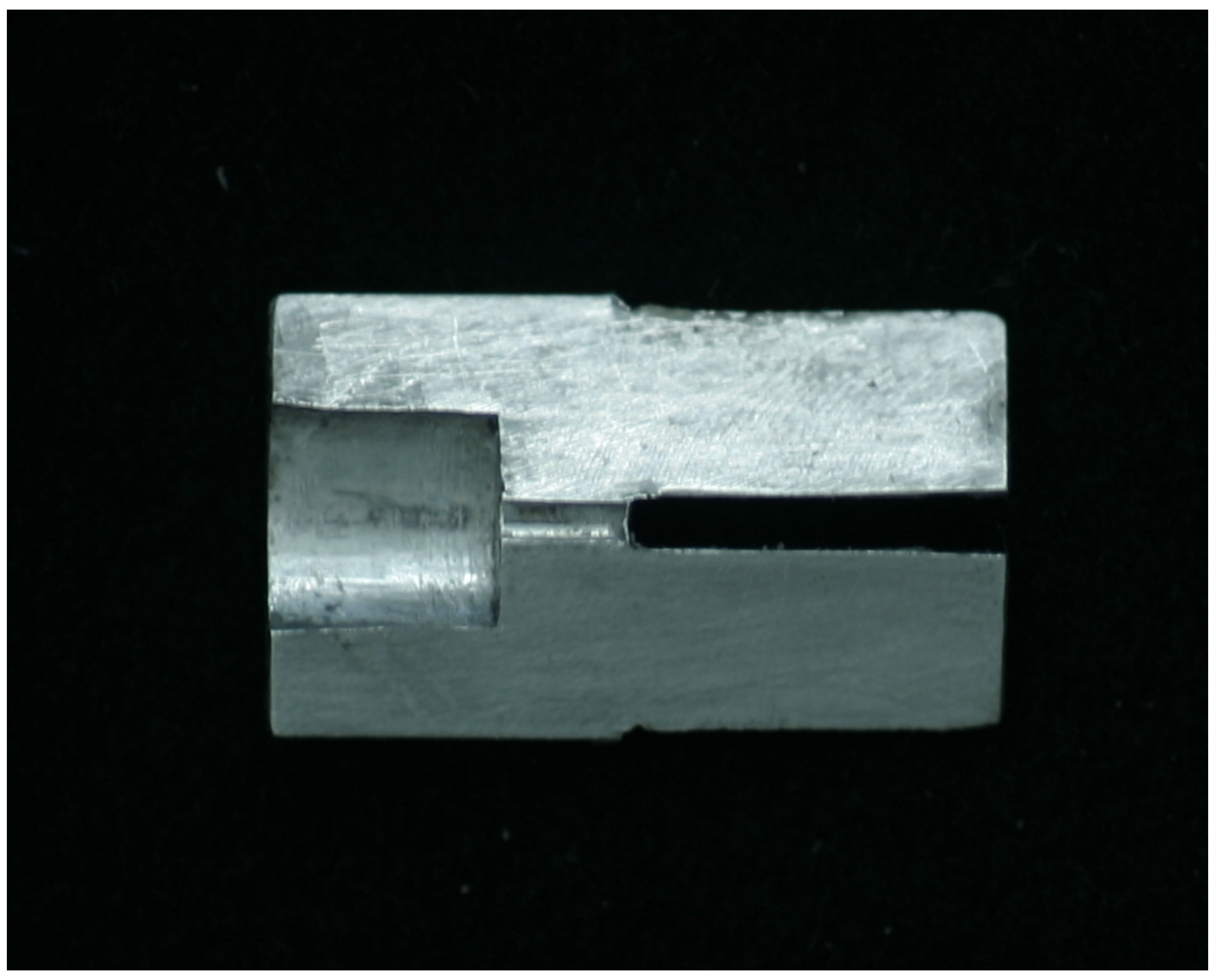


Fig. 8. Estrutura que contem /matem o cimento em contato com o pino (b), vista inferior e …

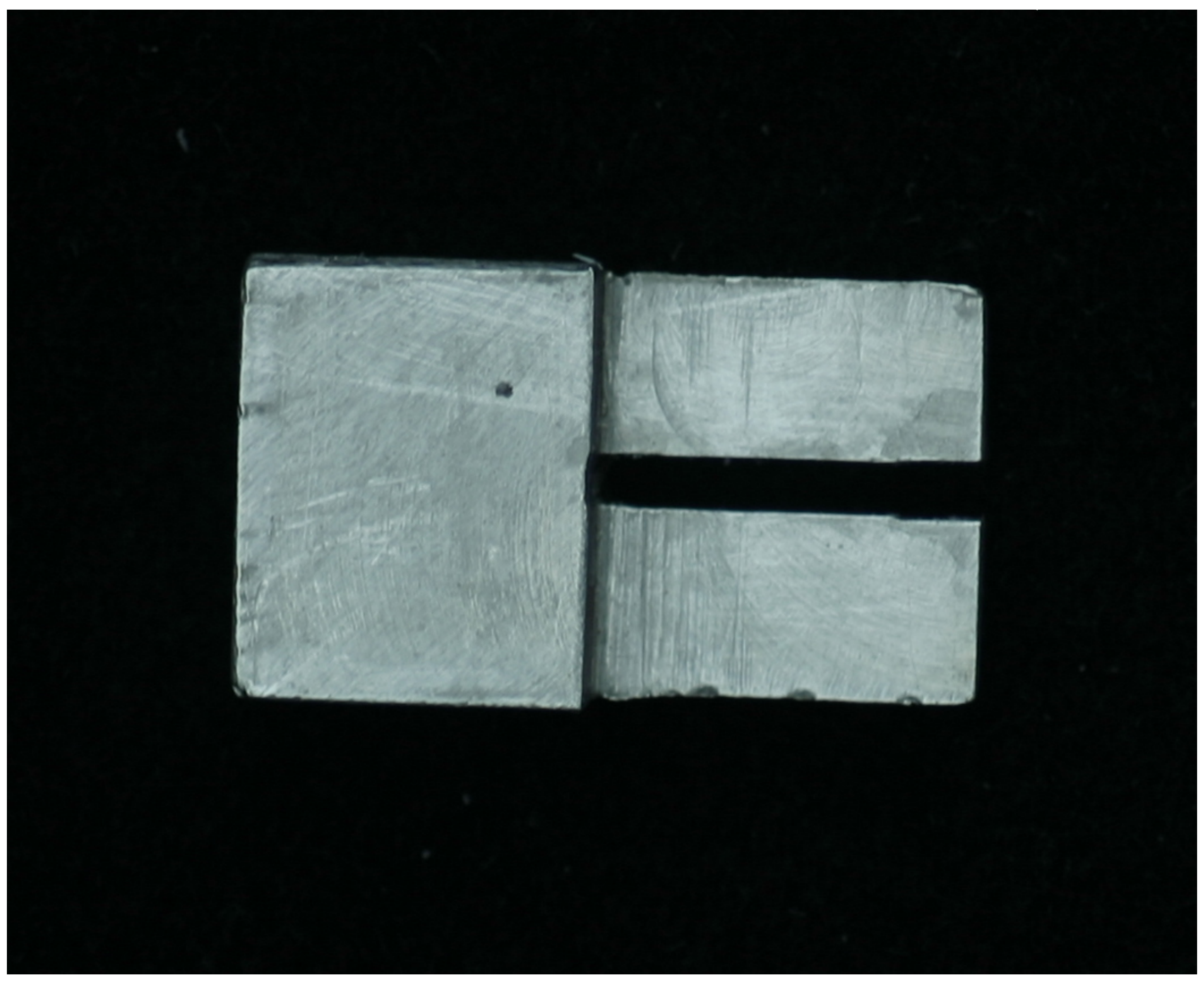


Fig. 9 … vista superior.

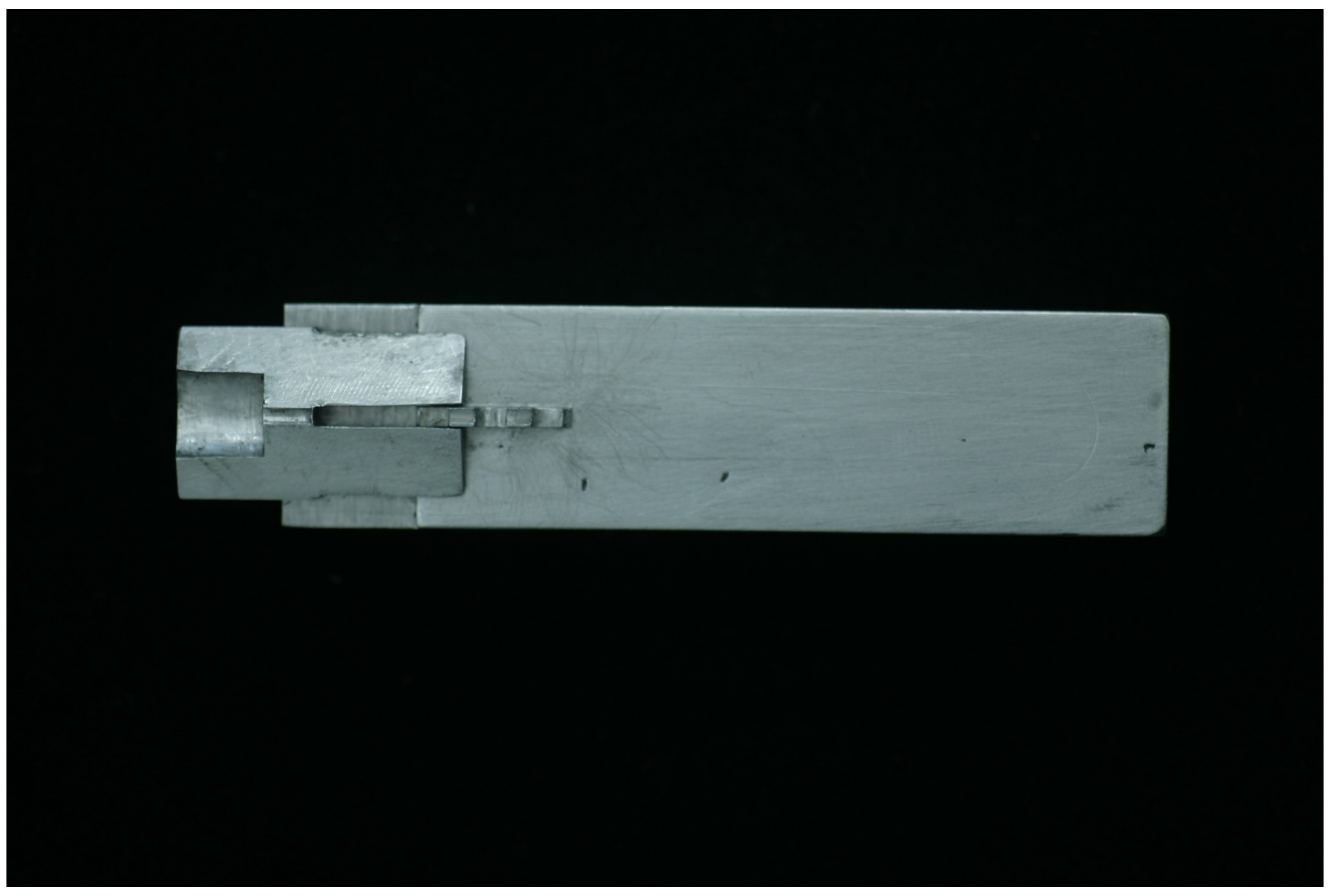


Fig. 10. Pormenor do sistema de encaixe entre a estrutura e que contém/mantém (b) e a que divide o cimento (c), vista superior, …

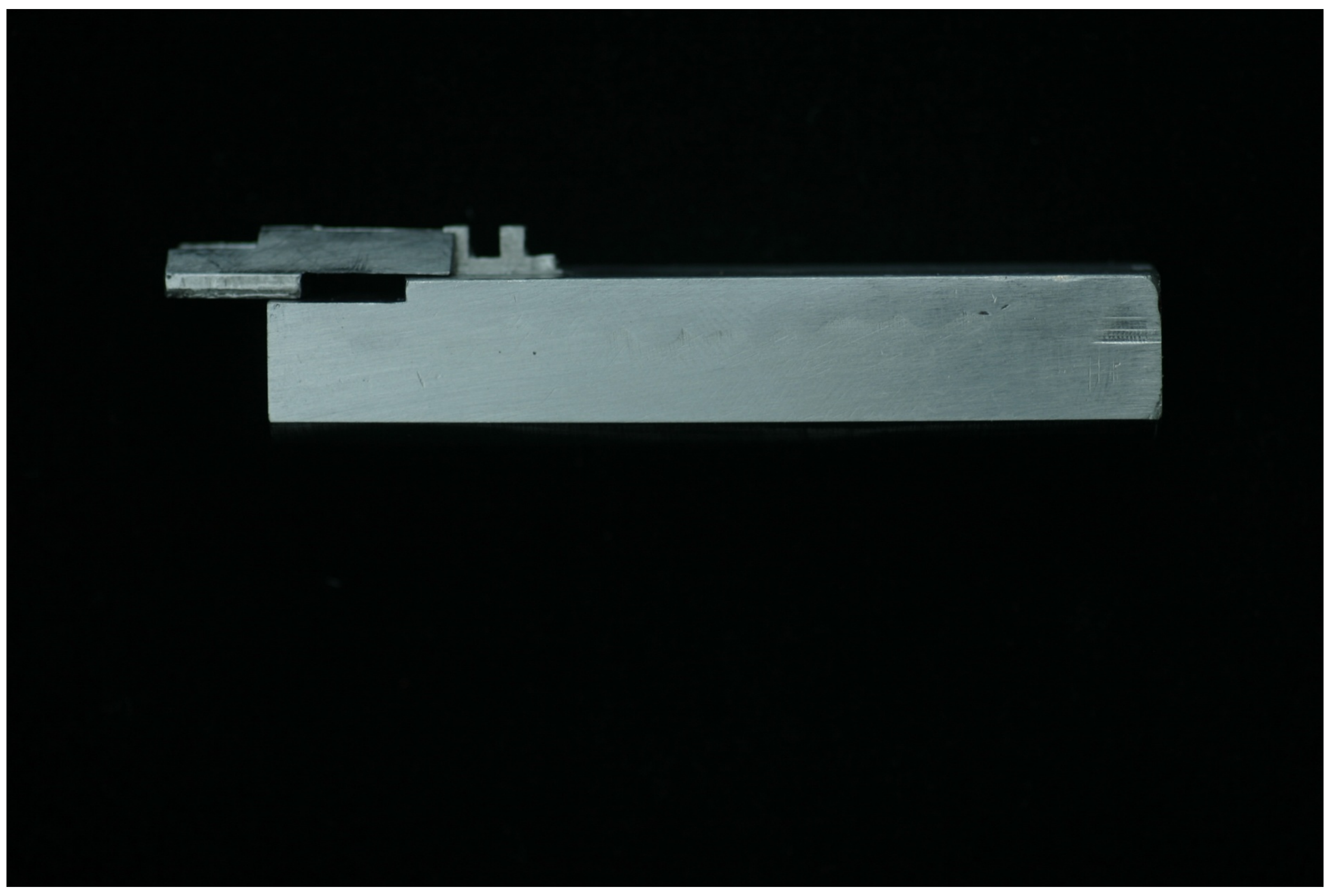


Fig. 11 … vista lateral, …

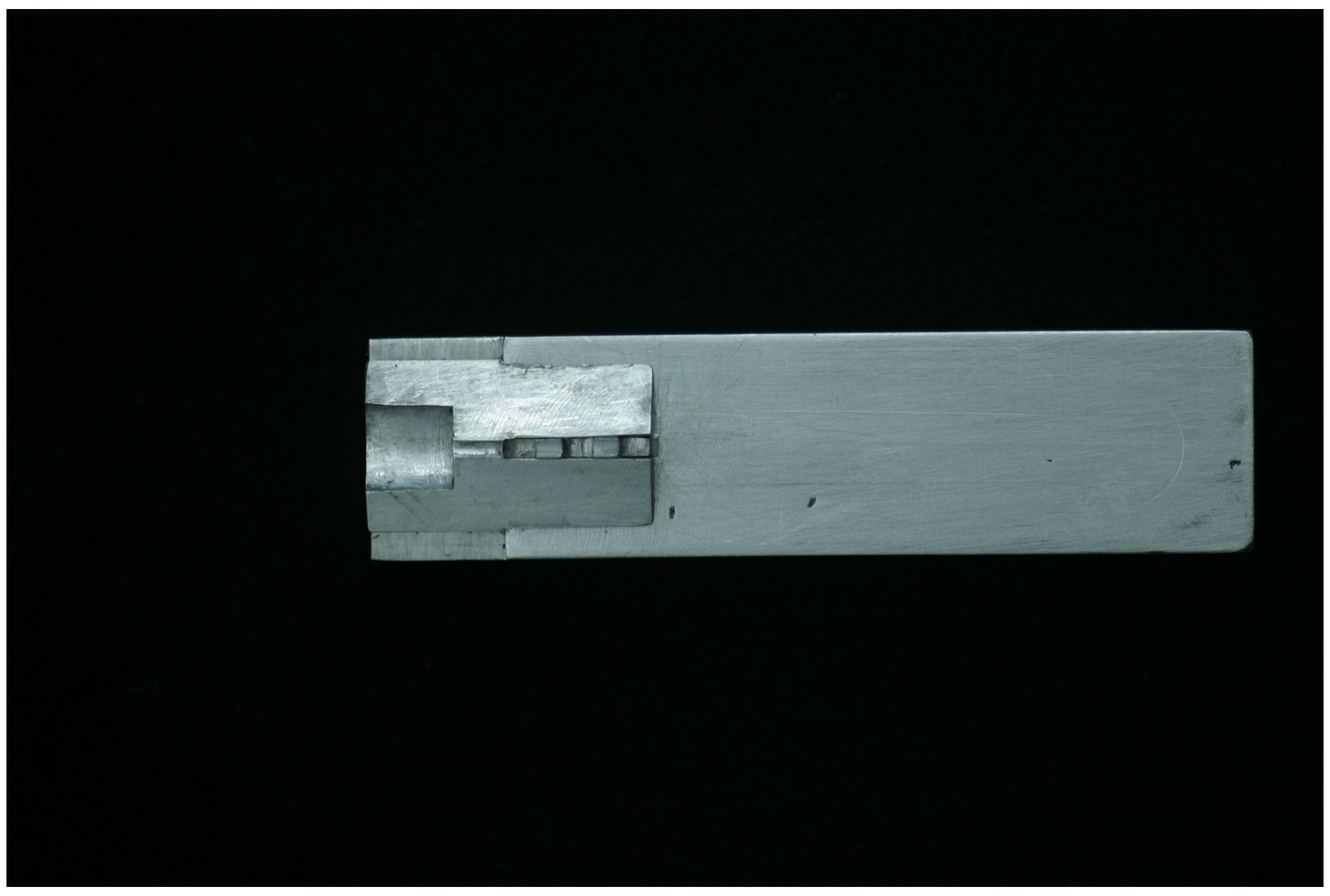


Fig. 12 … vista superior após o encaixe e …

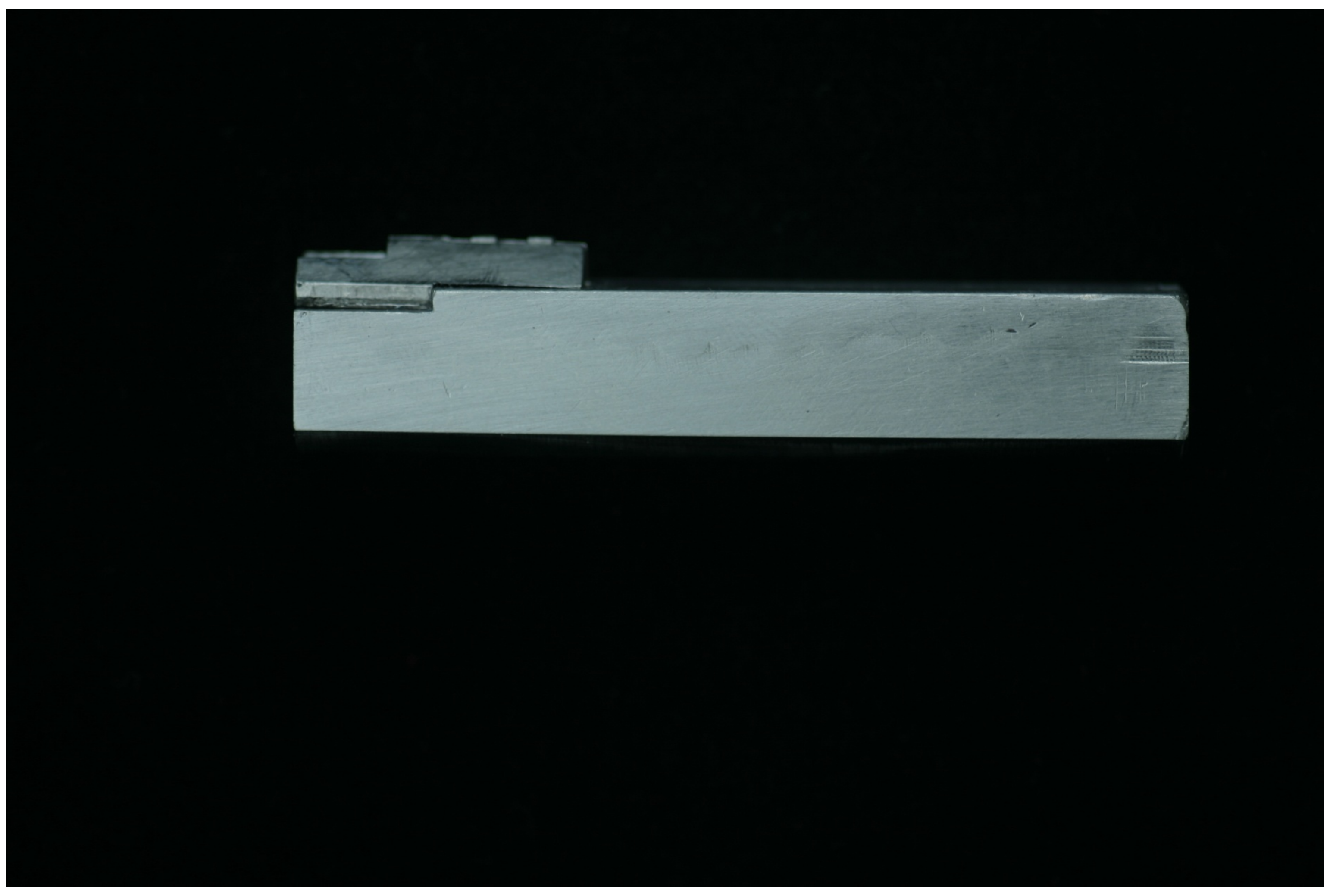


Fig. 13 … vista lateral após o encaixe.

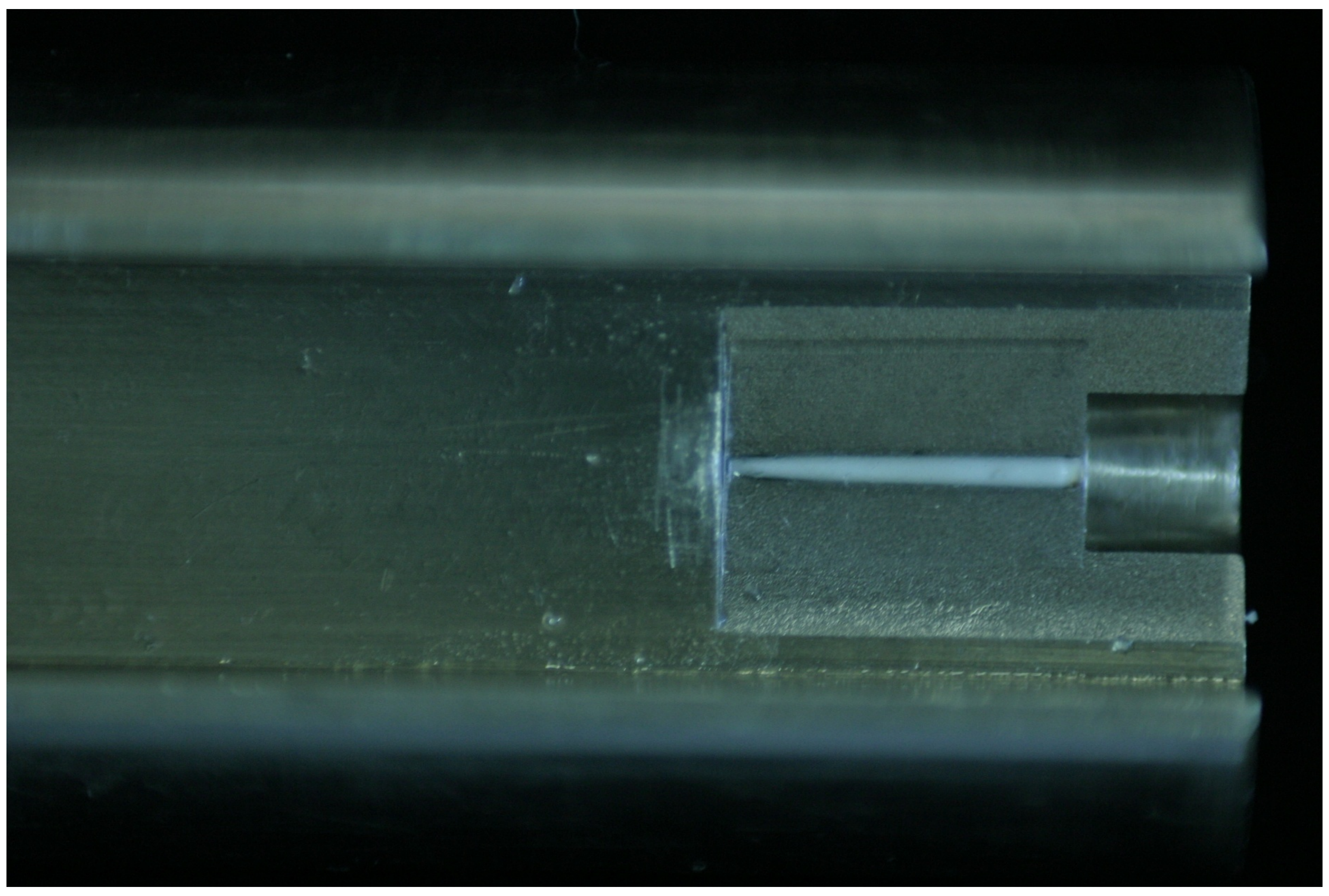


Fig. 14. Corpo da matriz (a) com o pino sobreposto por uma tira de poliéster ...

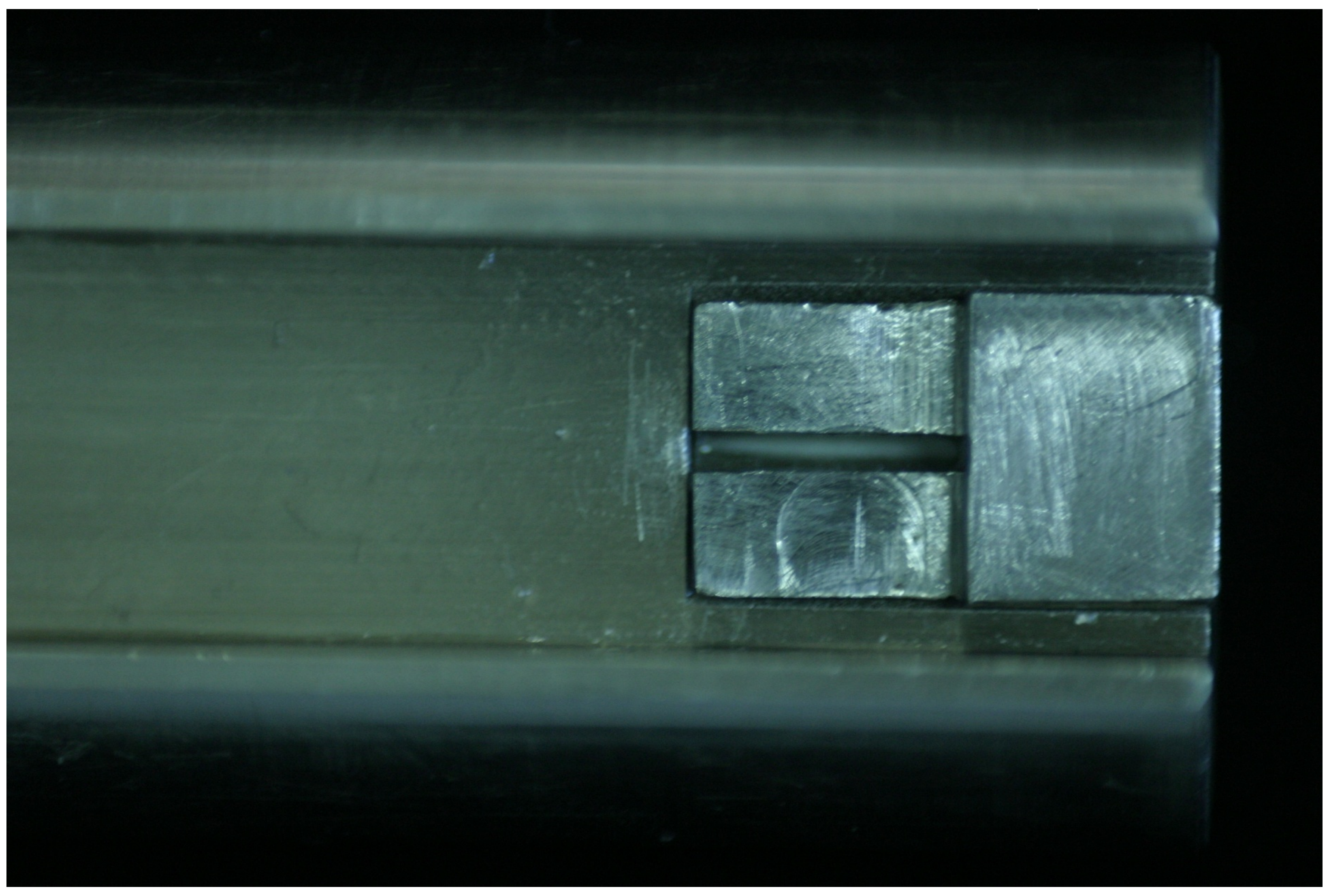


Fig. 15. …estrutura que contém o cimento (b) devidamente lubrificada em posição.

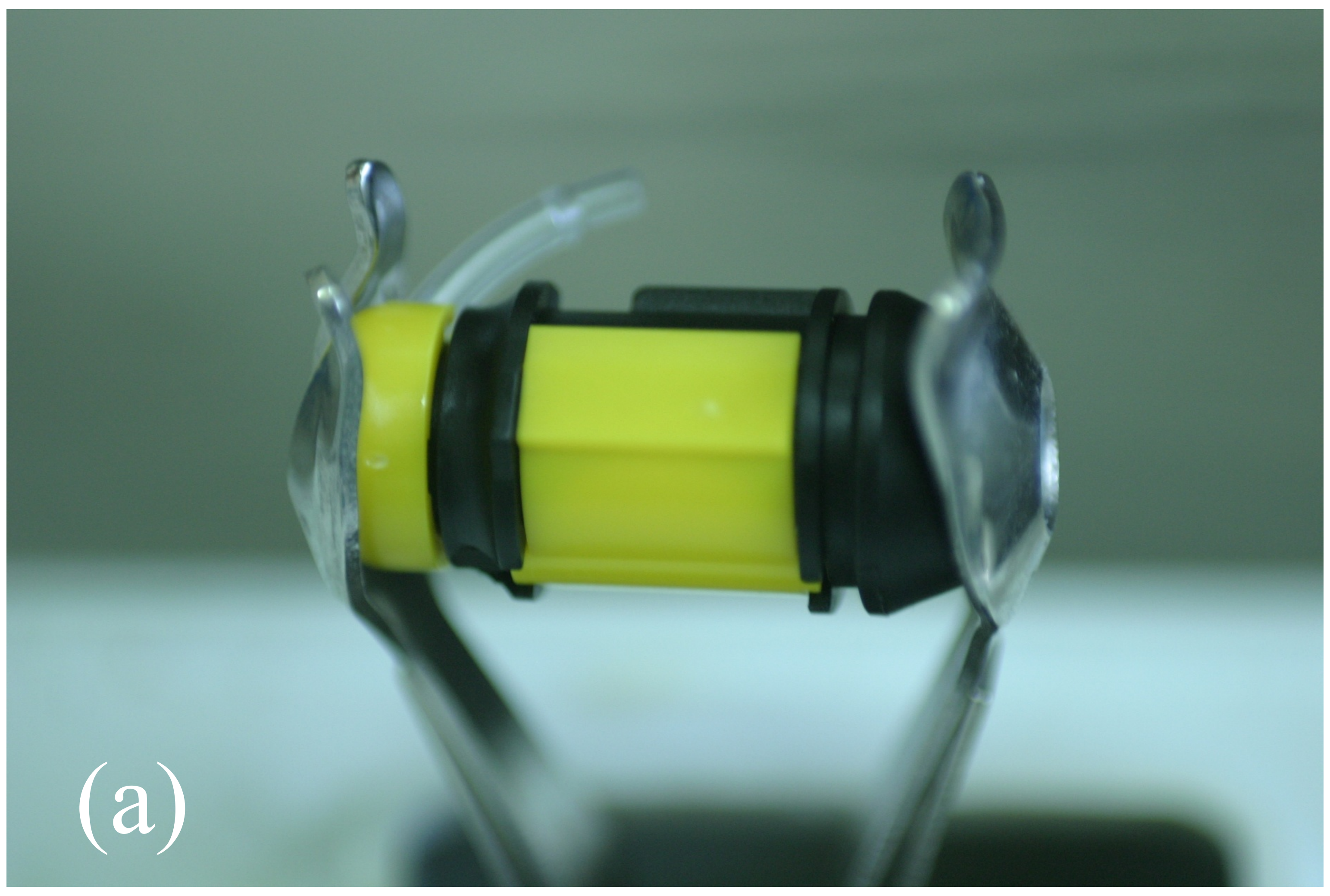


Fig. 16 a e b. Cimento resinoso auto-condicionante de dupla polimerização (Rely-X Unicem).

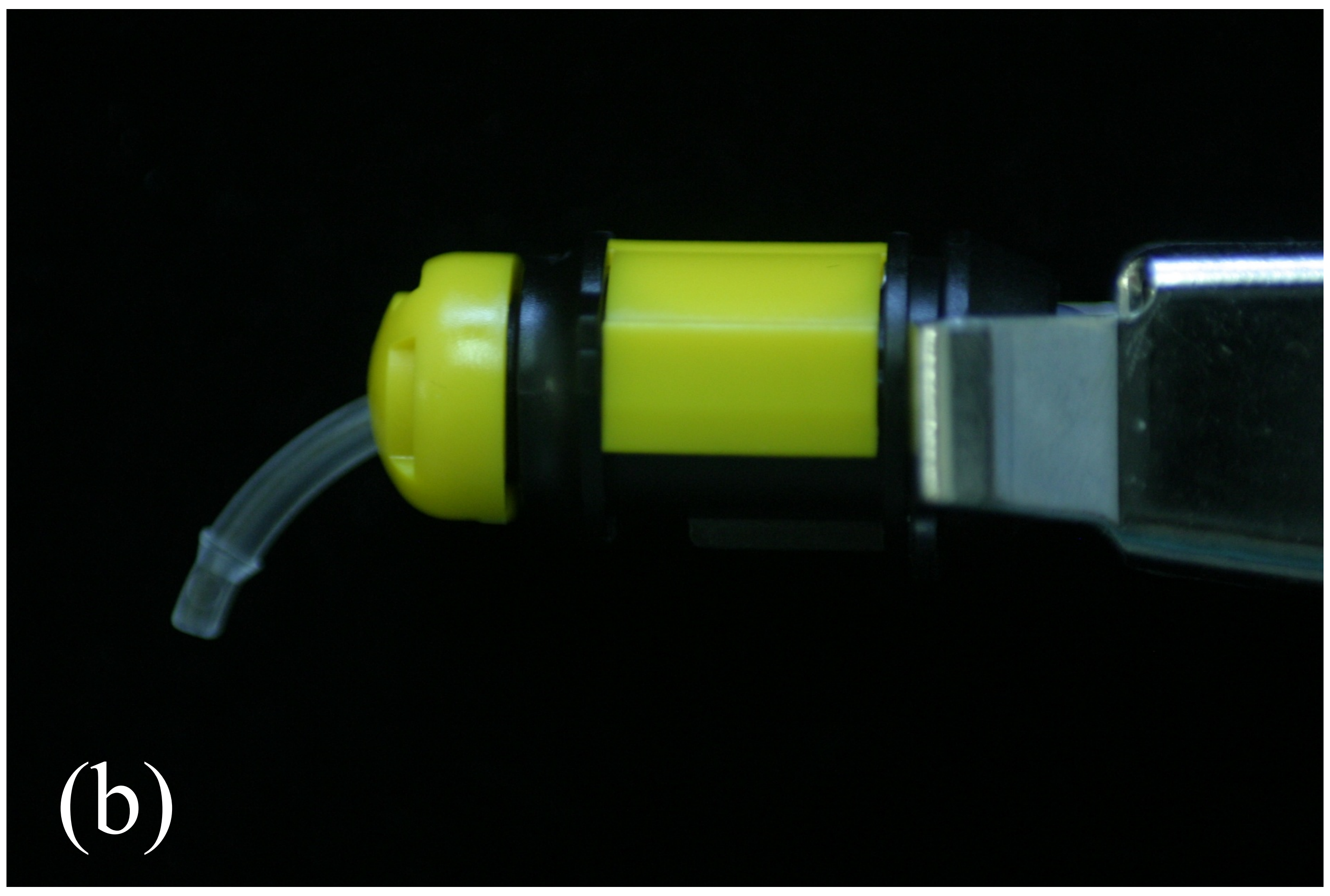


Fig. 16 b.

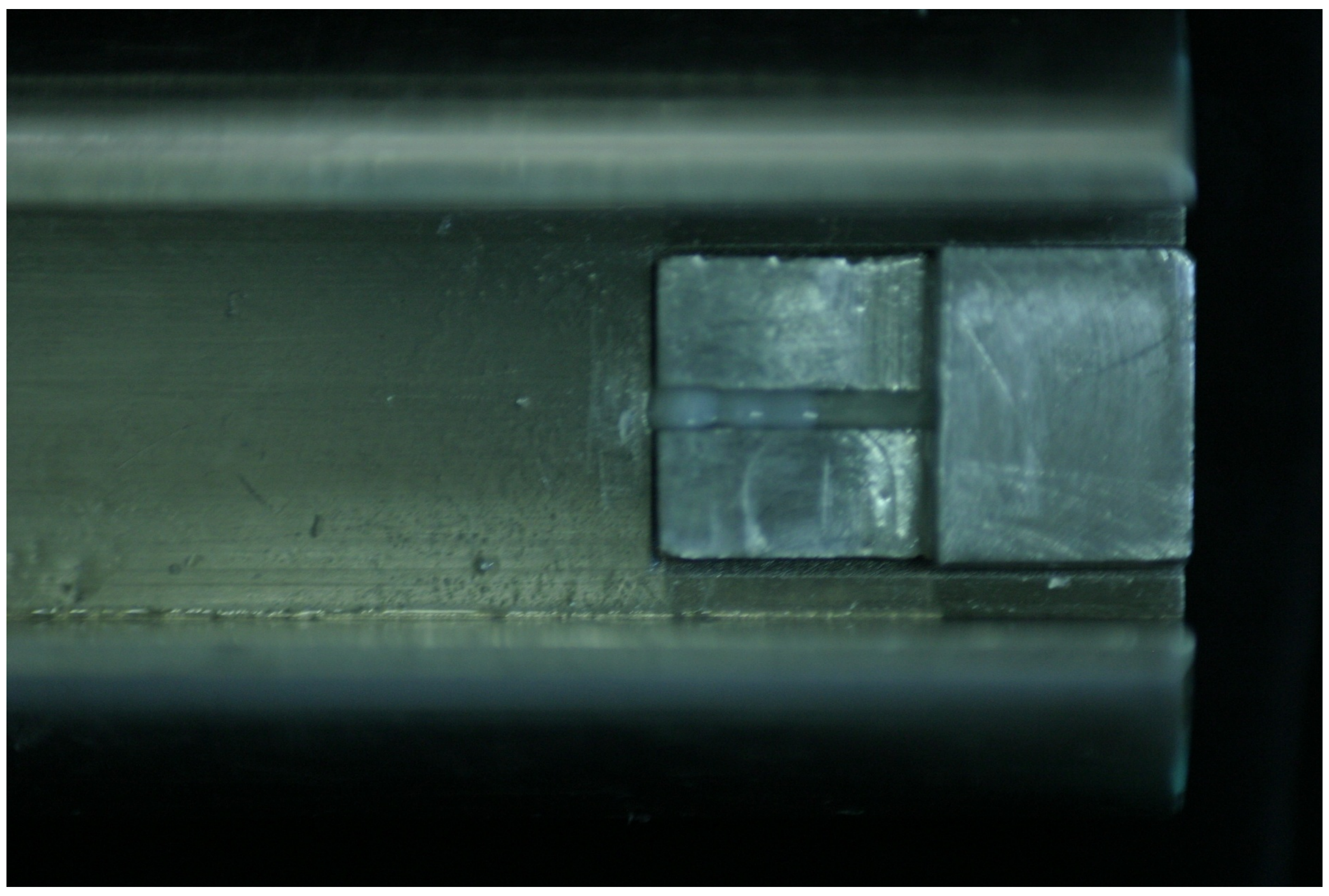


Fig. 17. Aplicação do cimento resinoso no espaço da estrutura que o contem o cimento (b).

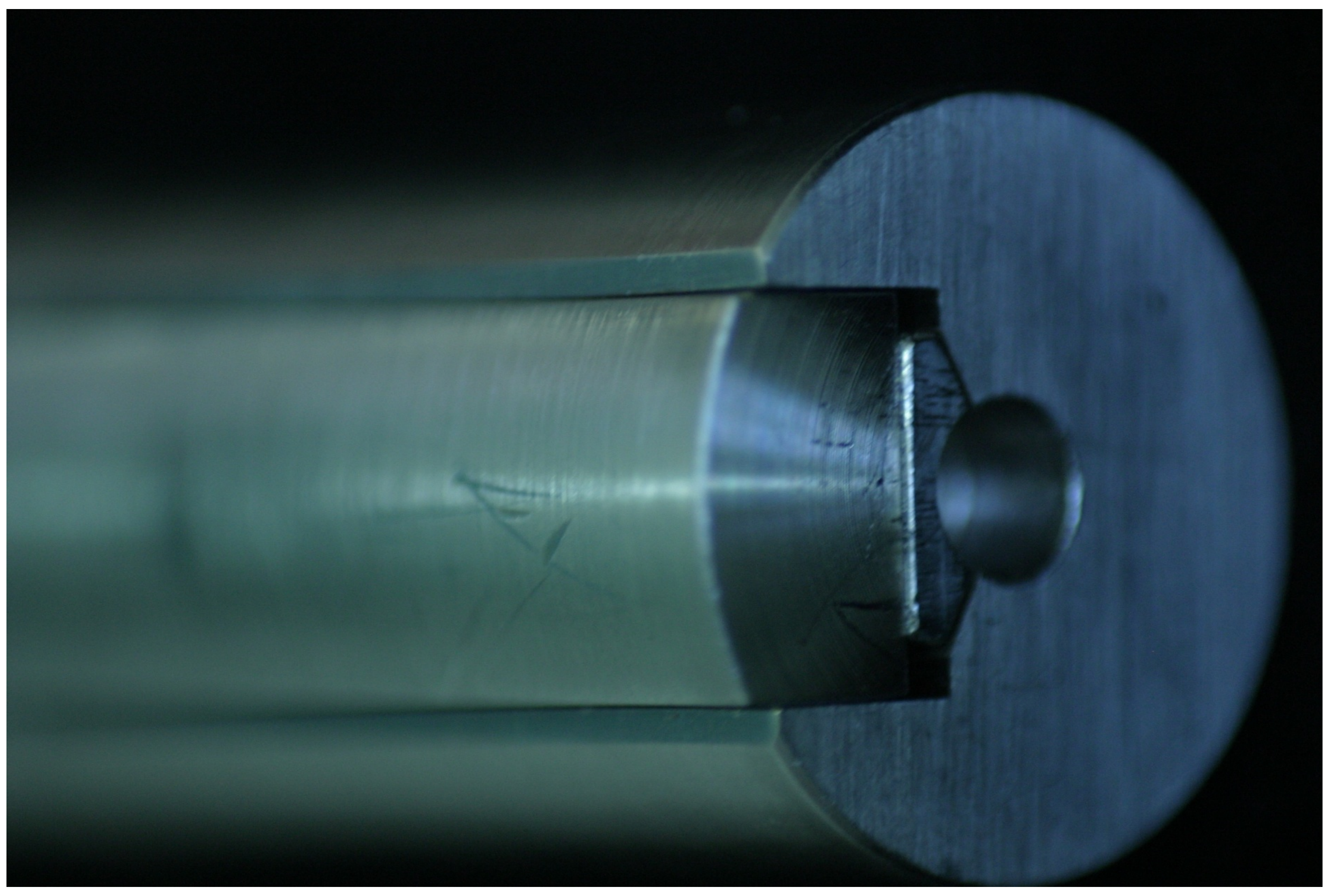


Fig. 18. Conjunto após a colocação da estrutura que divide o cimentos em blocos (c).

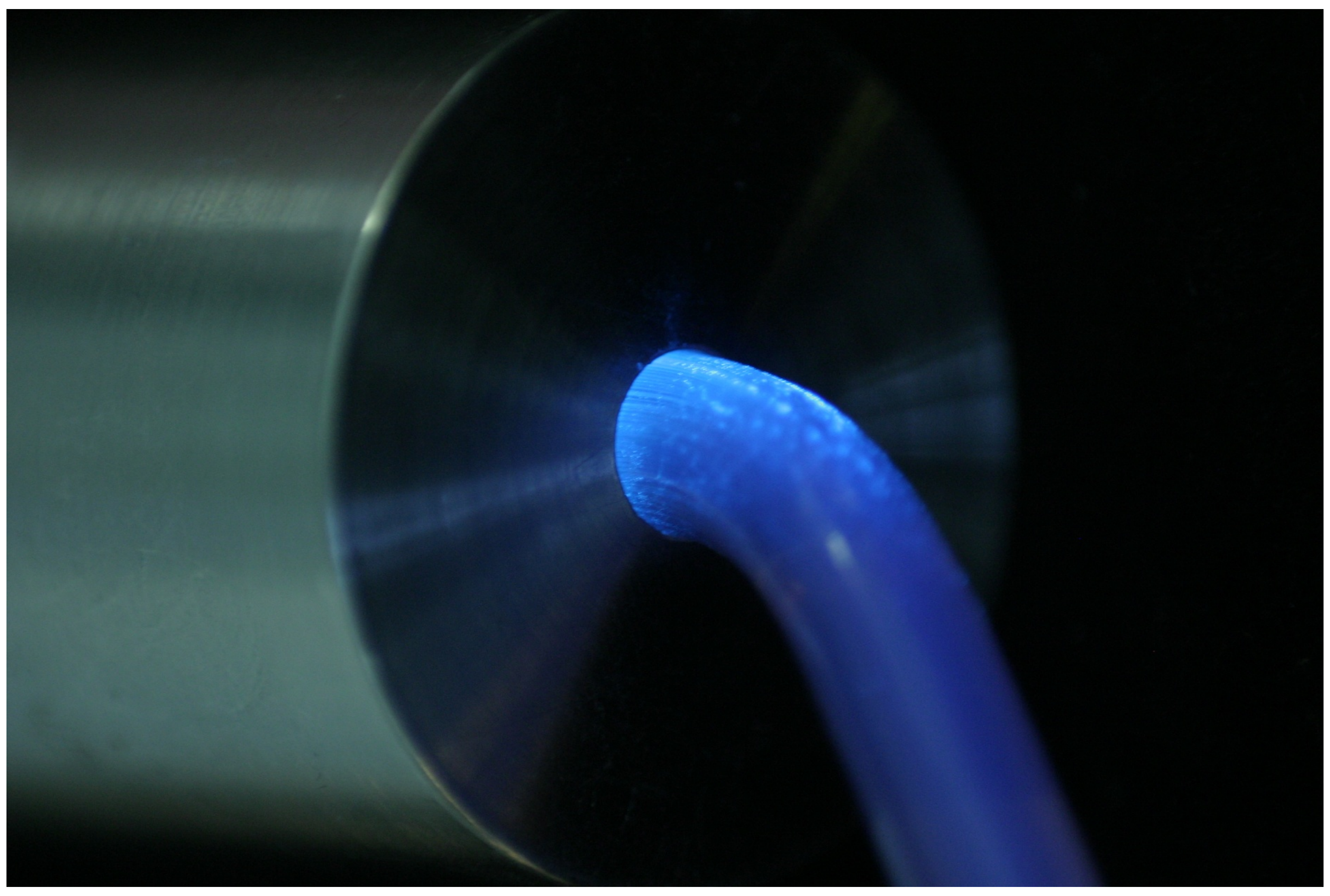


Fig. 19. Conjunto após a colocação do cilindro externo (d) e a ponta do aparelho fotopolimerizador.

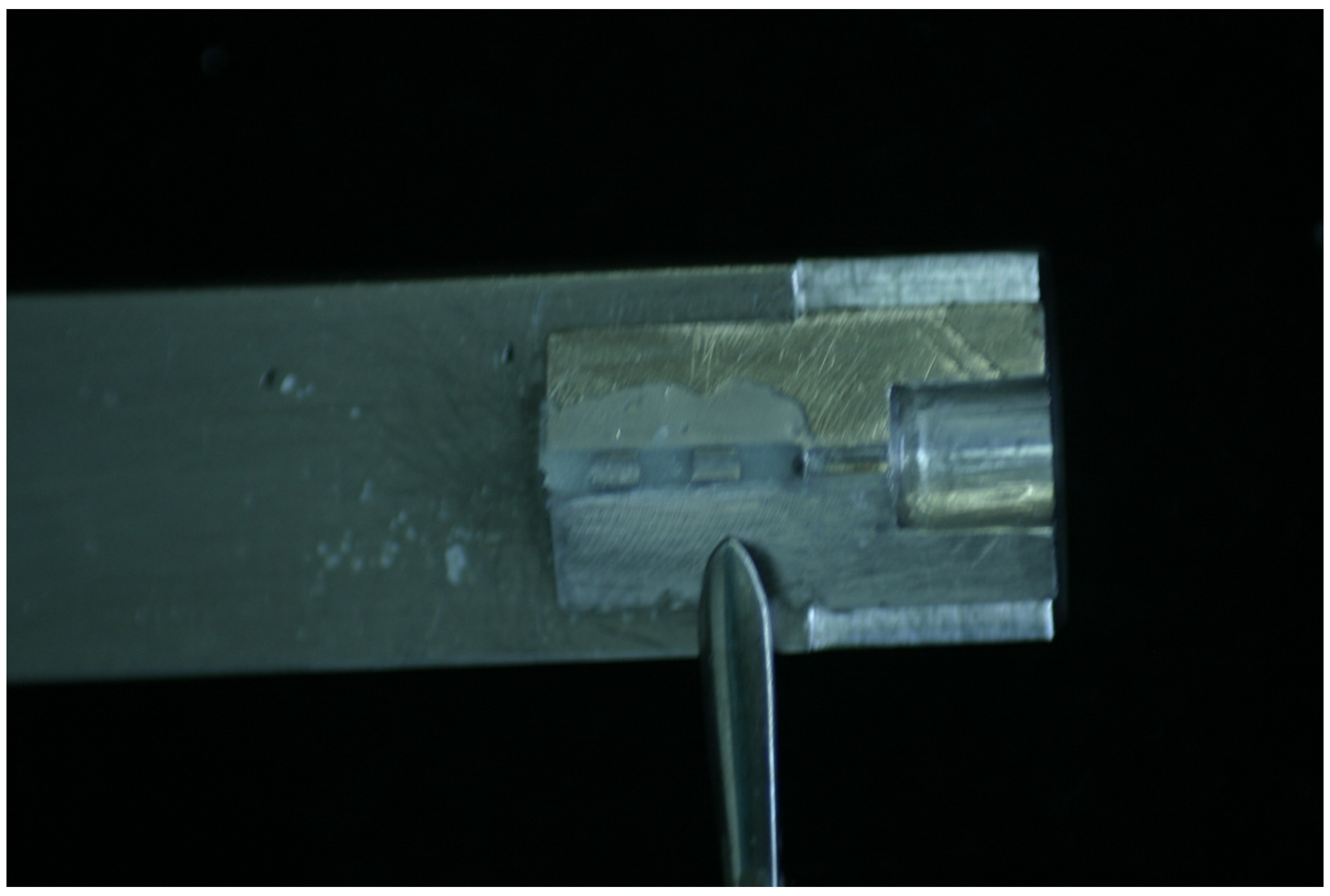


Fig. 20. Remoção dos excessos de cimento após 10 minutoss (Incluindo 40 seg de fotopolimerização).

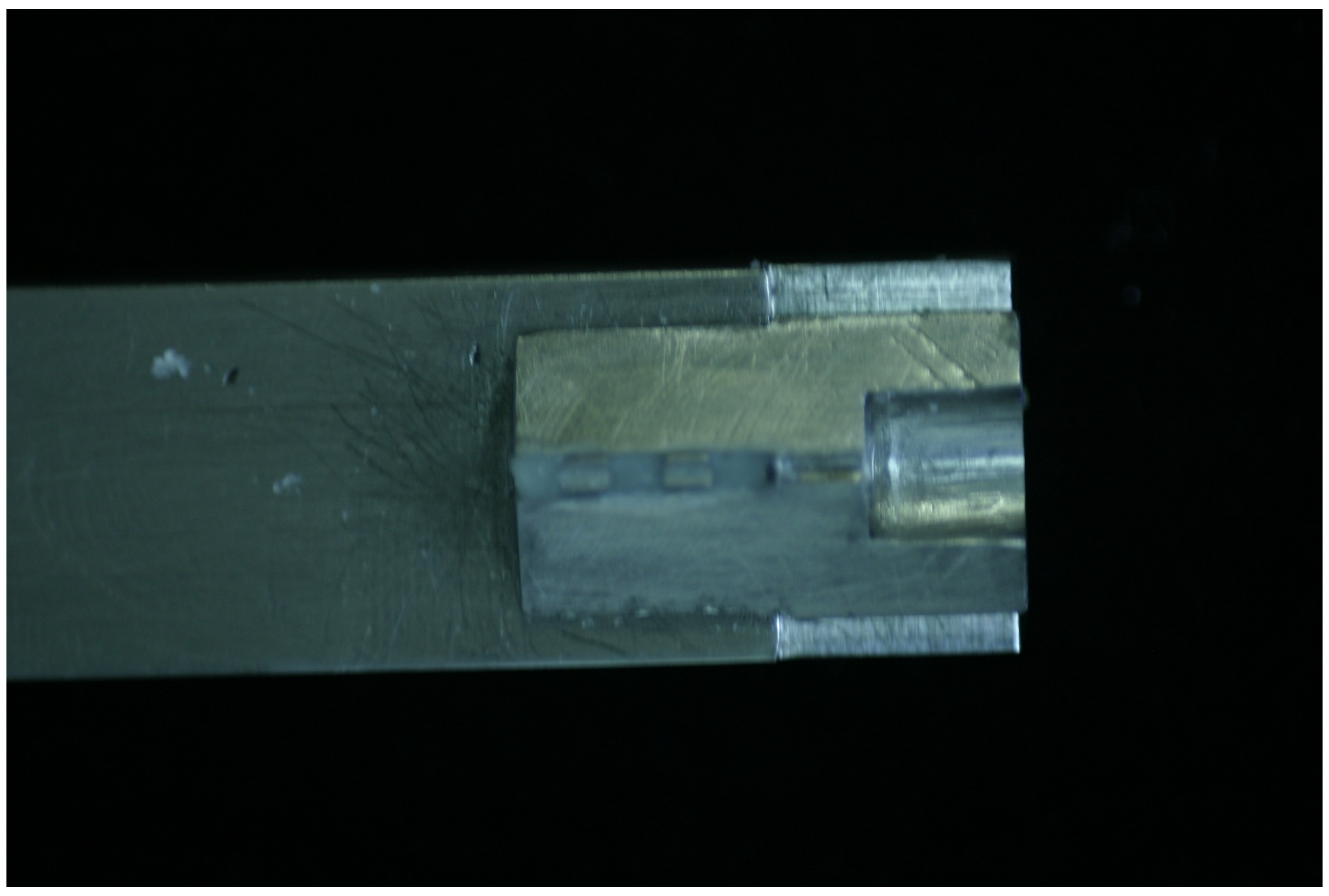


Fig. 21. Aspecto após a remoção dos excessos de cimento.

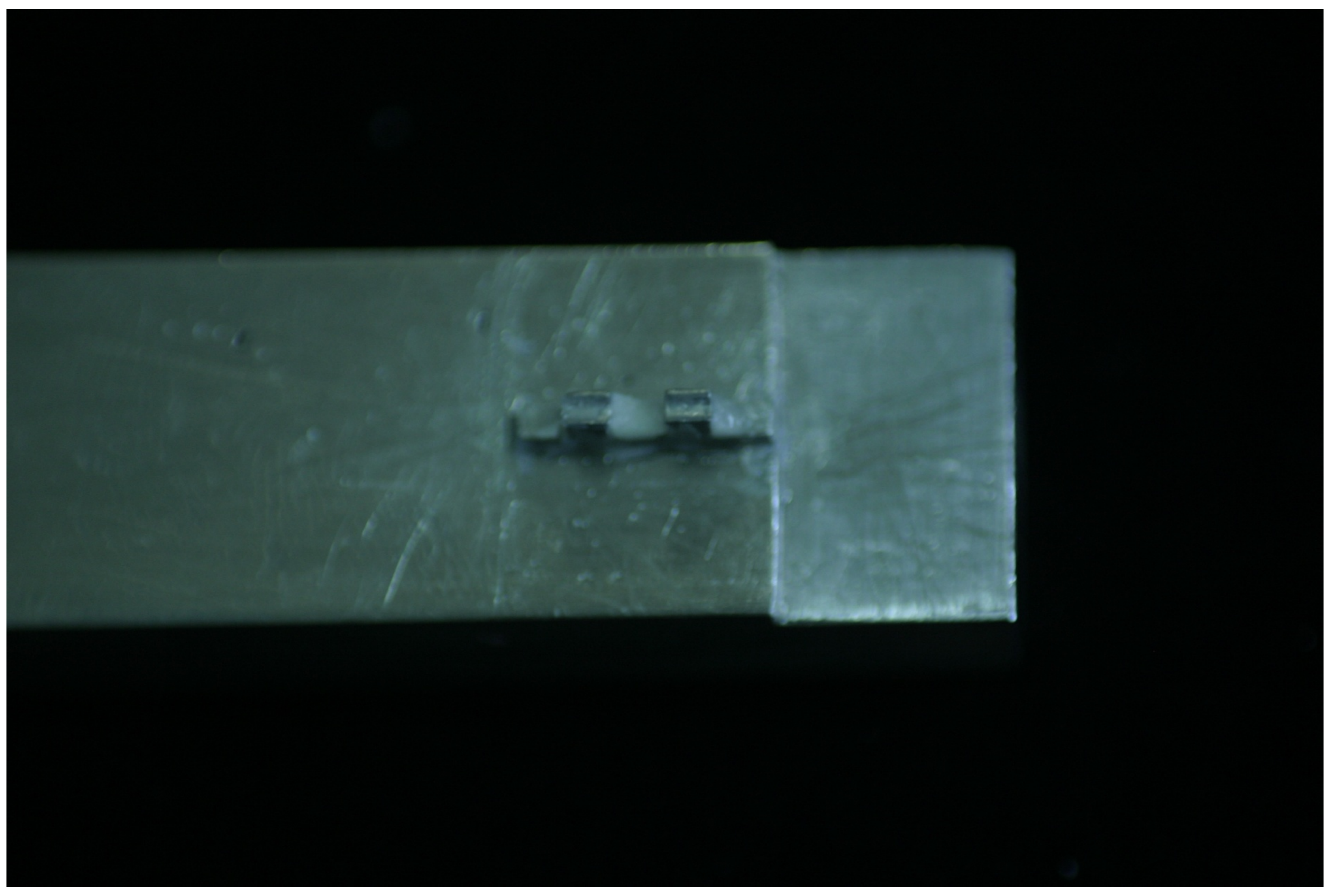


Fig. 22. Aspecto da estrutura metálica que divide o cimento (c) após a remoção da estrutura que contem os blocos resinosos (b).

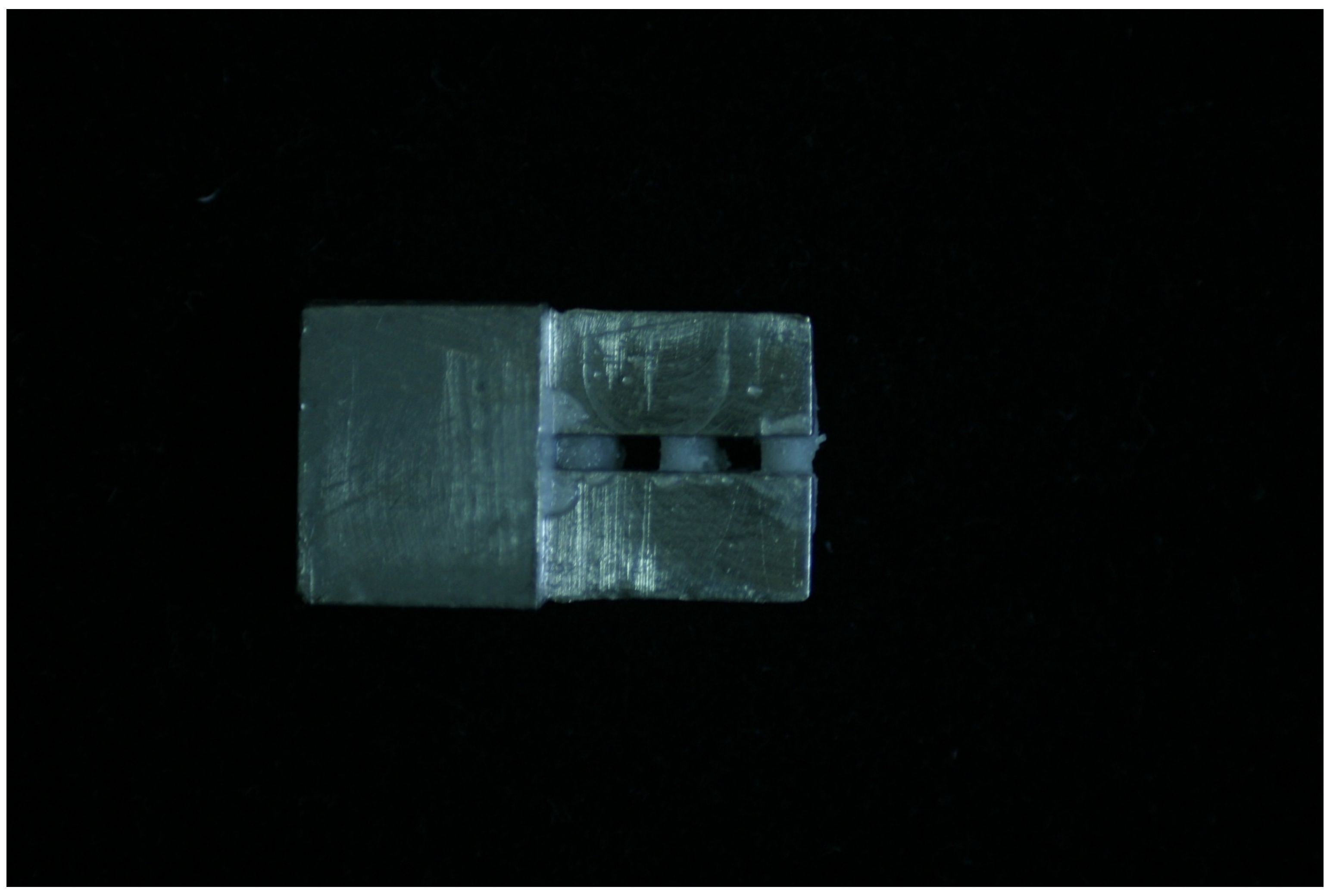


Fig. 23. Aspecto da estrutura metálica que contém o cimento (b) após sua remoção com os blocos resinosos ,vista superior, ...

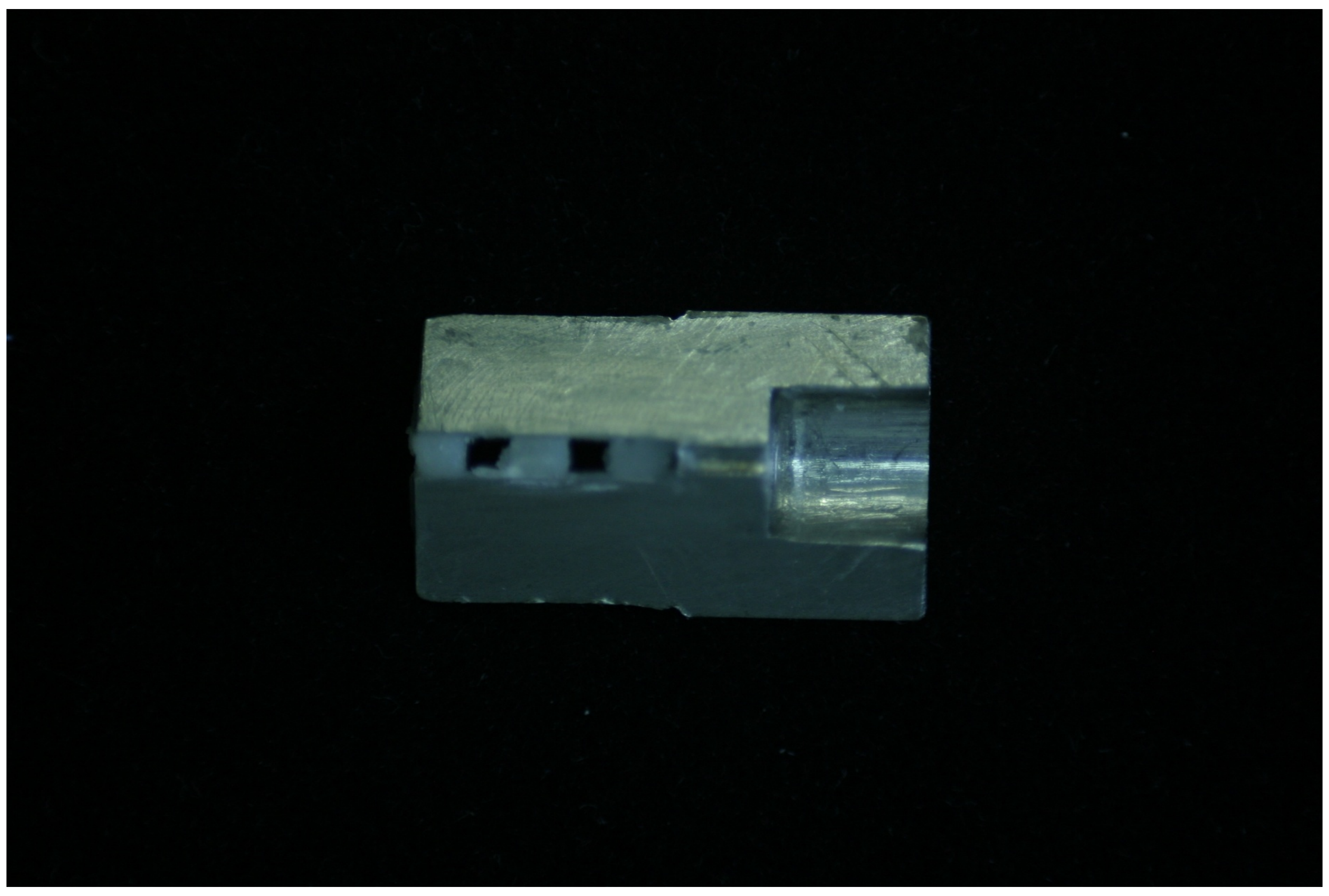


Fig. 24. …vista inferior e …

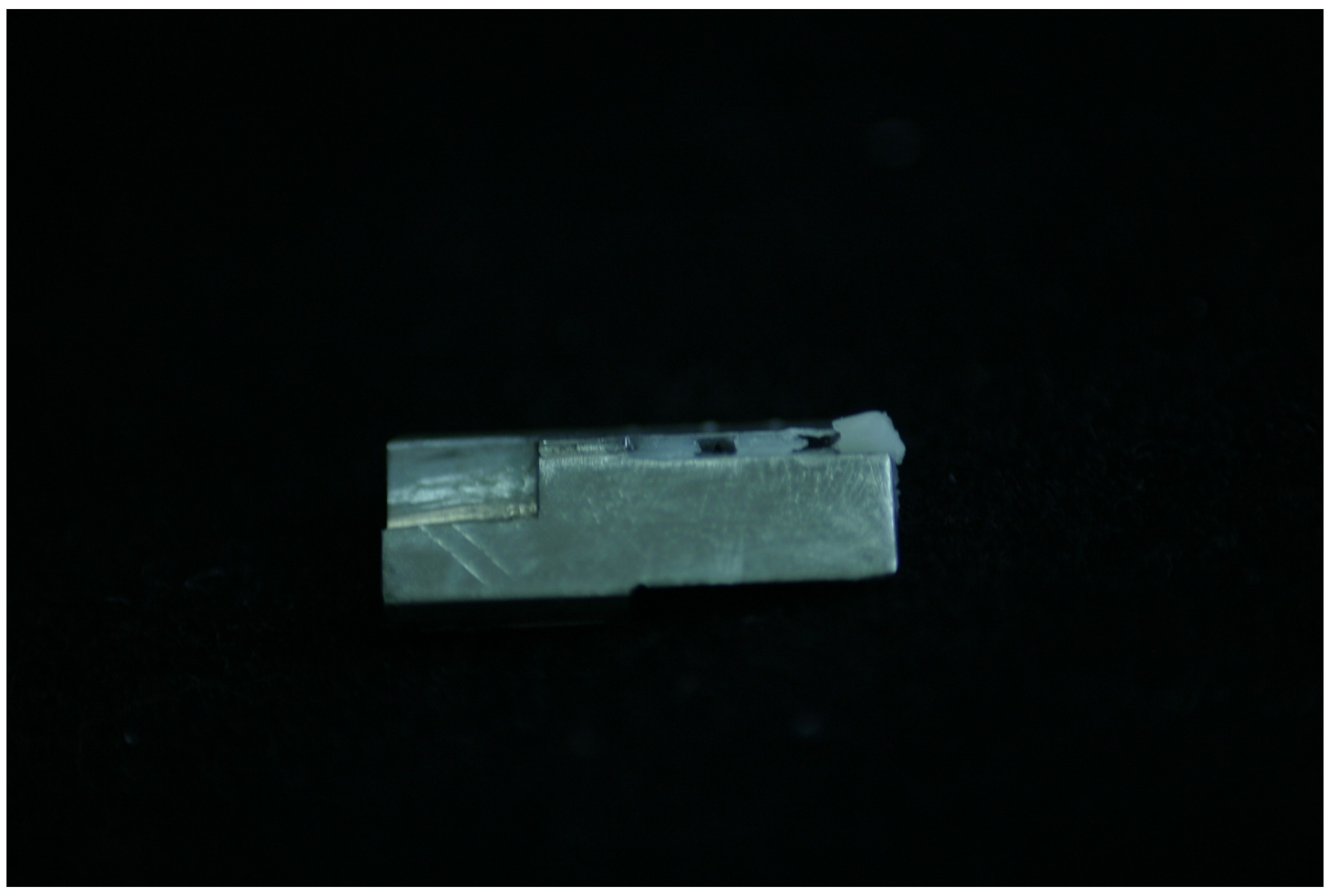


Fig. 25. …vista lateral.

Fig. 26. Bloco de cimento resinoso após sua remoção da estrutura que contém o cimento (b). Três vezes de aumento.

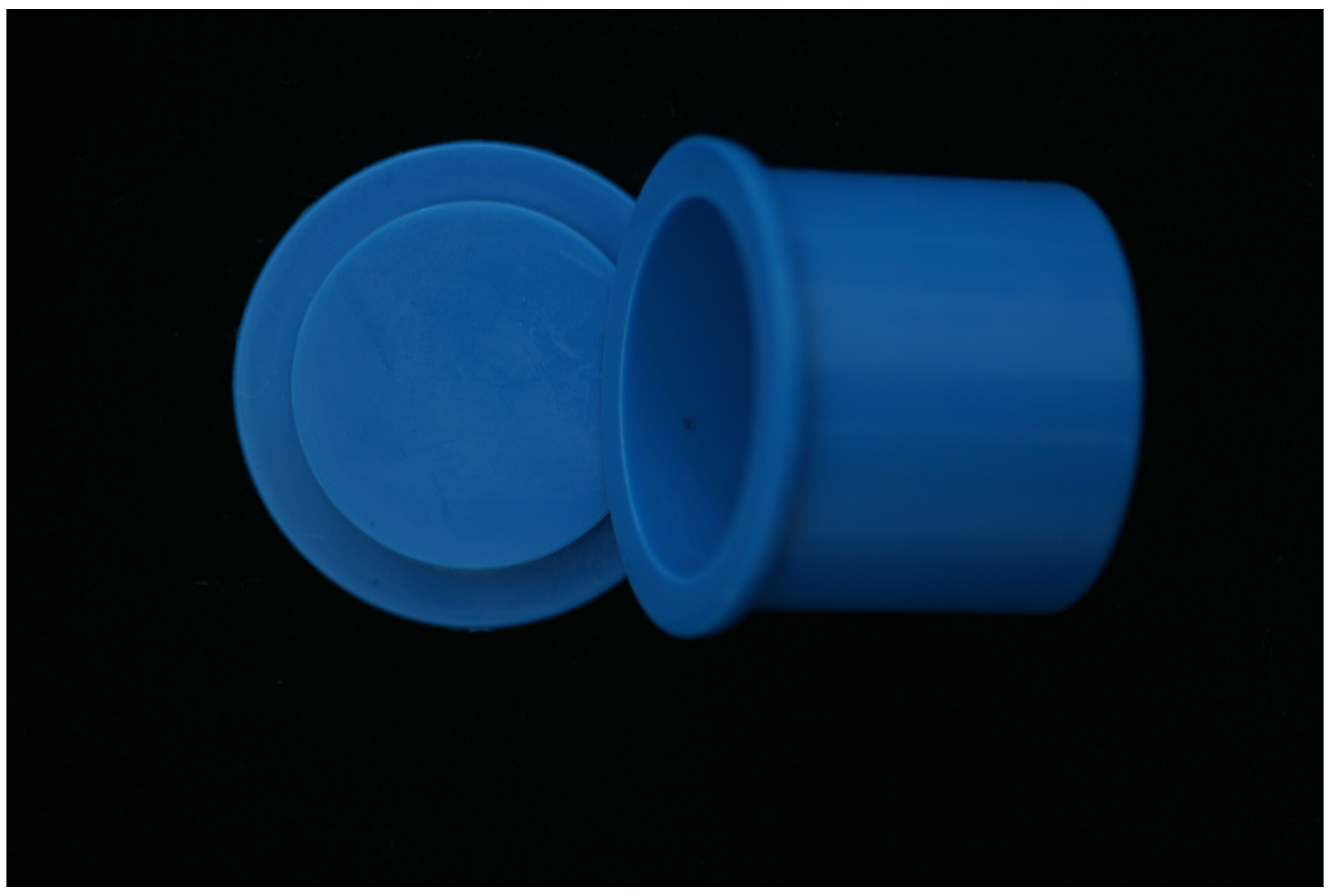


Fig. 27. Cilindro plástico (Buehler) utilizados para conter os blocos de cimento resinoso e a resina de inclusão.

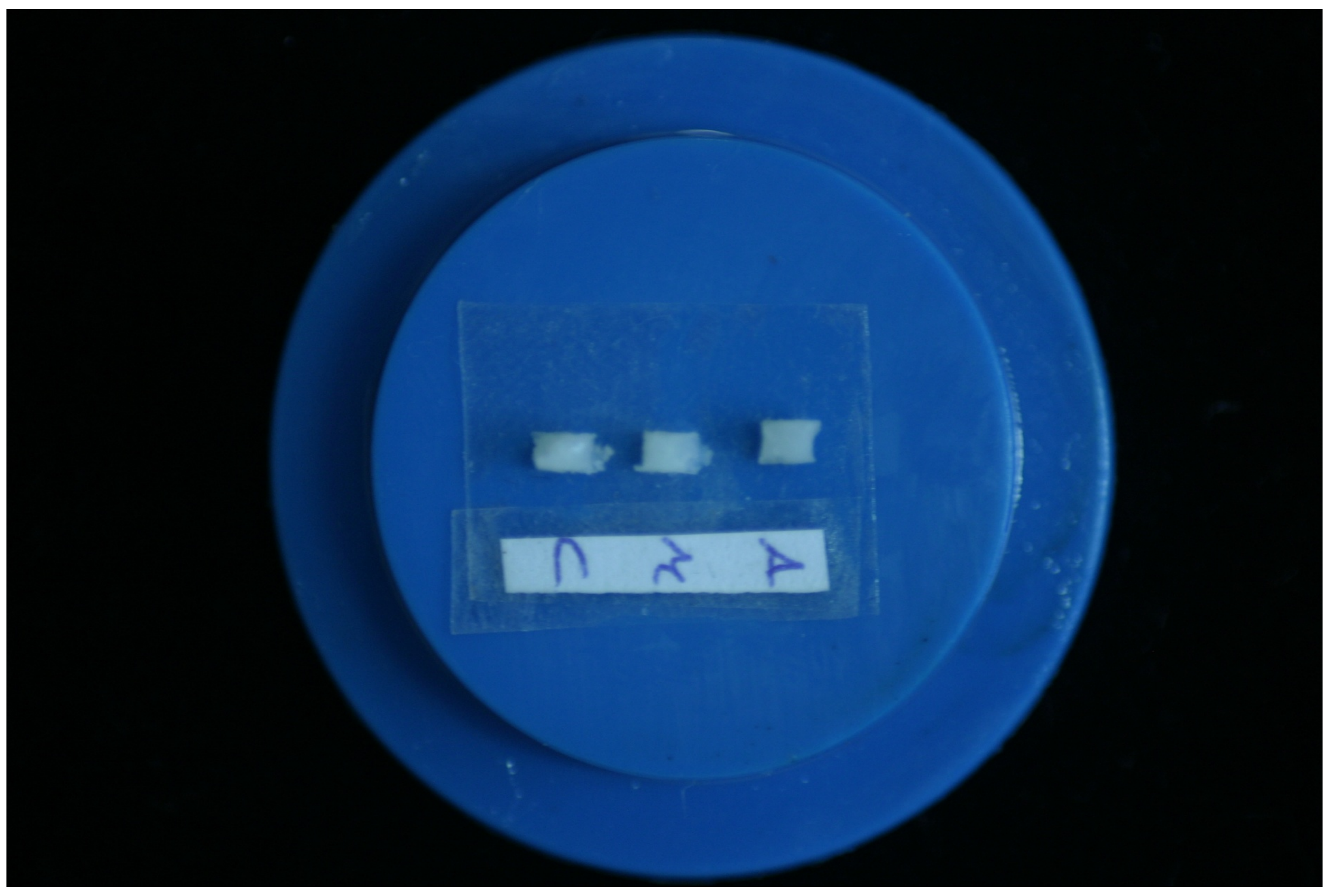


Fig. 28. Blocos de cimento resinoso em posição previamente a inserção da resina de inclusão devidamente identificados (TA, TM e TC).

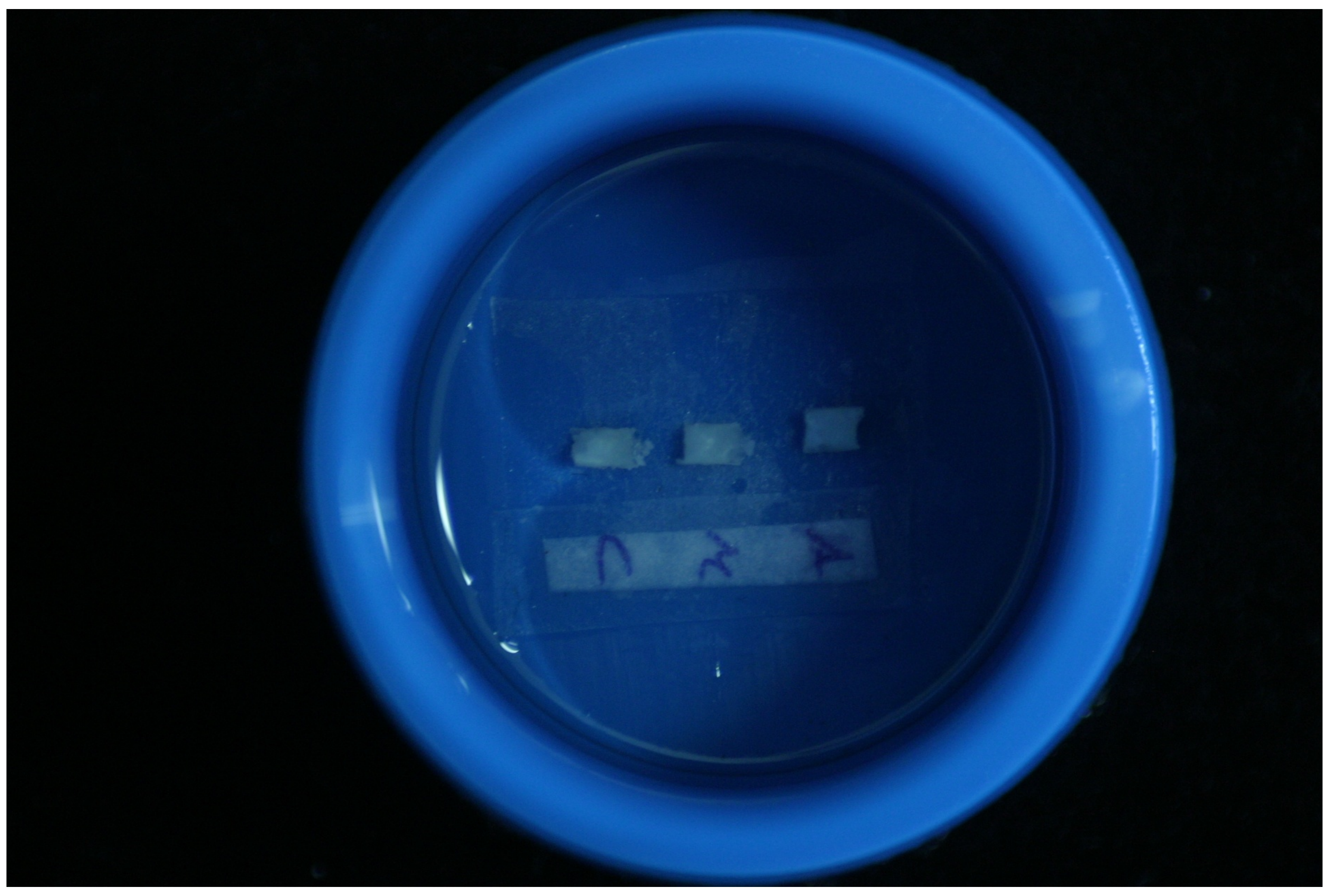


Fig. 29. Cilindro plástico (Buehler) montado com os blocos de cimento resinoso e...

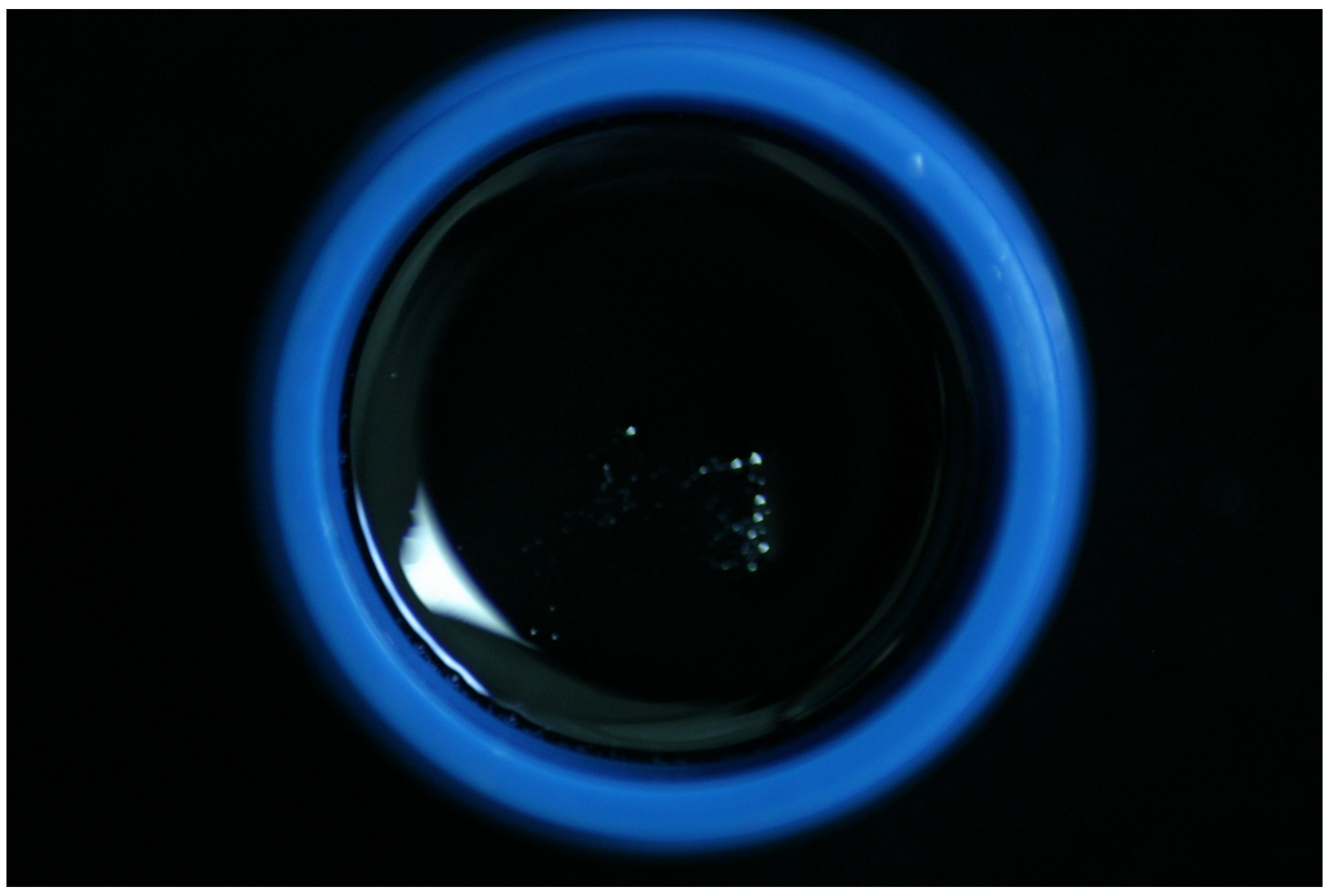


Fig. 30. … logo após a inserção da resina de inclusão (Acrílica tipo Cristal).

Fig. 31 a e b. Equipamento de inclusão a vácuo (Cast N'Vac, Buehler).

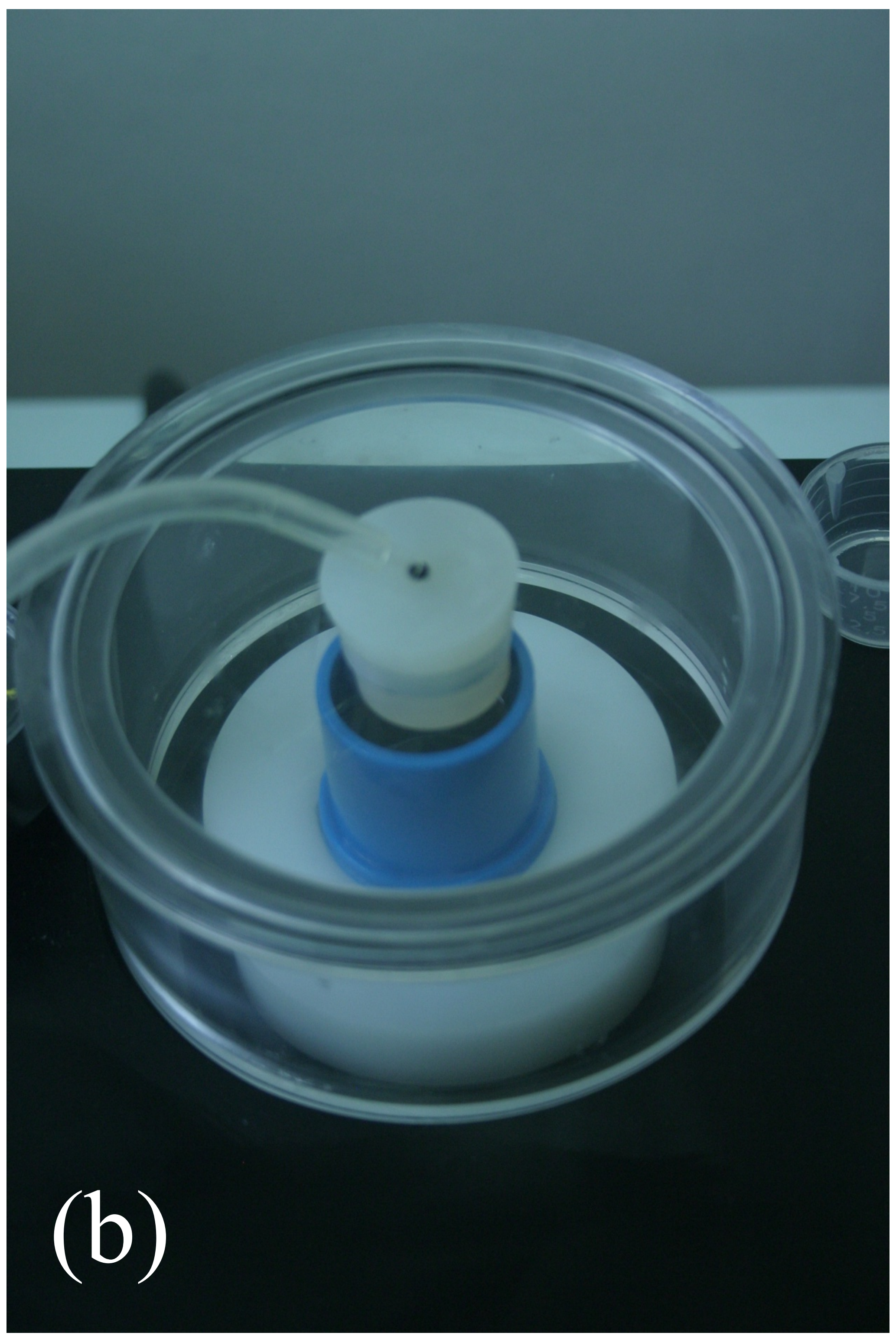


Fig. 31 b.

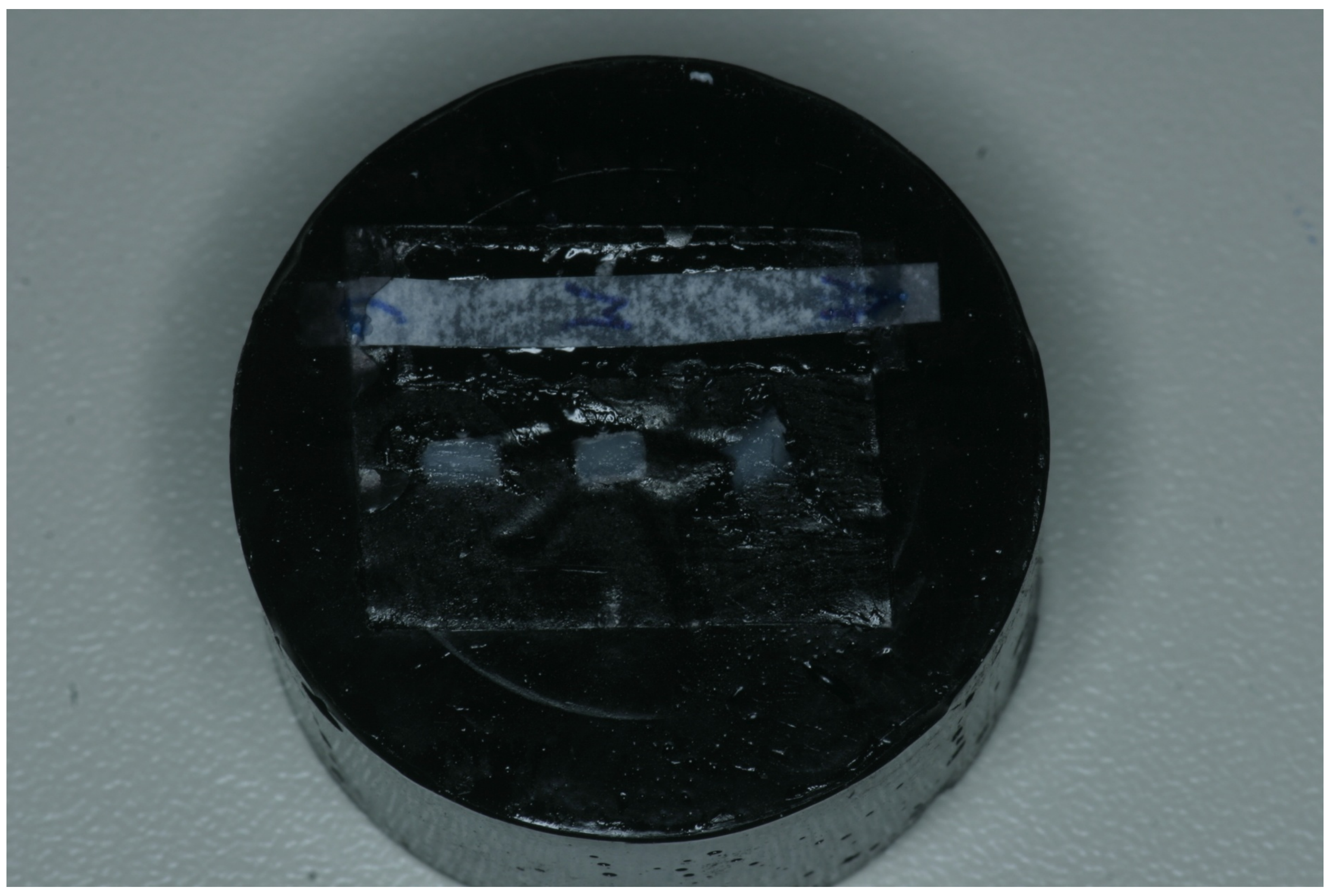


Fig. 32. Corpo-de-prova após a inclusão.

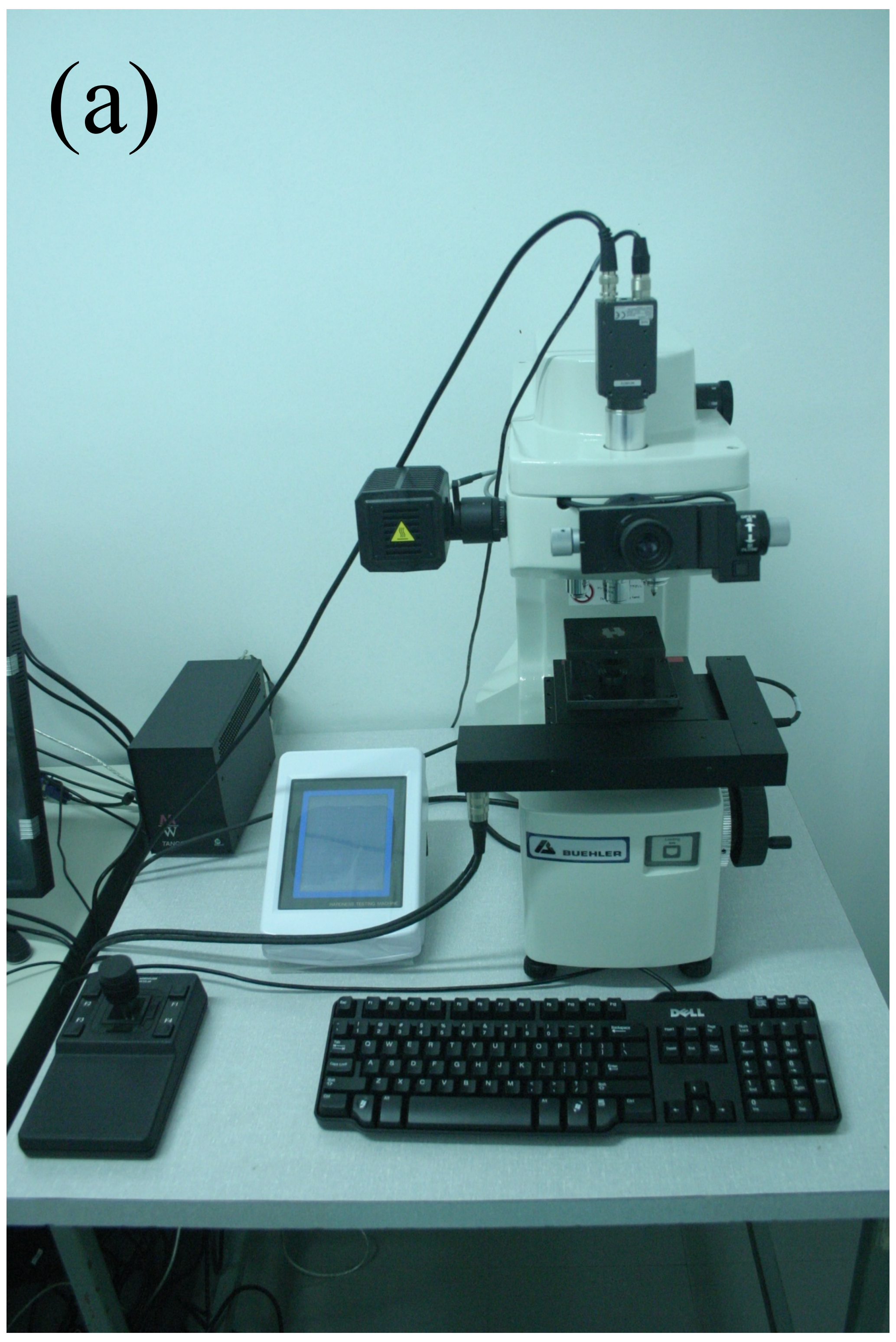


Fig. 33 a e b. Microdurômetro Micromet 5104 Buehler(a) e computador (b) para genrenciamento das imagens através do software Omnimet MHT.

5.3B Figuras do artigo 2 – RA (Push-out).

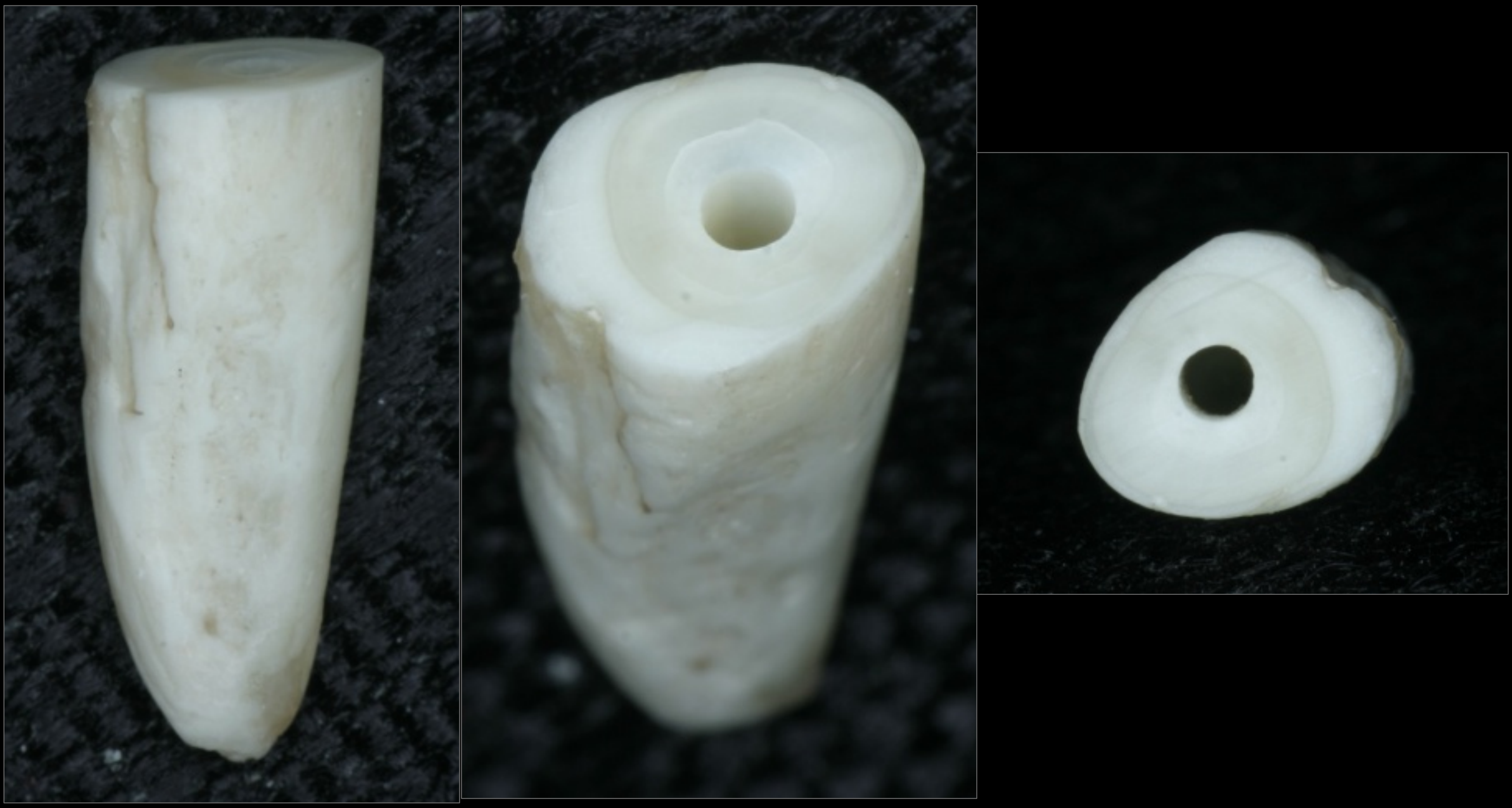


Fig. 1. Raízes selecionadas, limpas e condutos radiculares preparados.

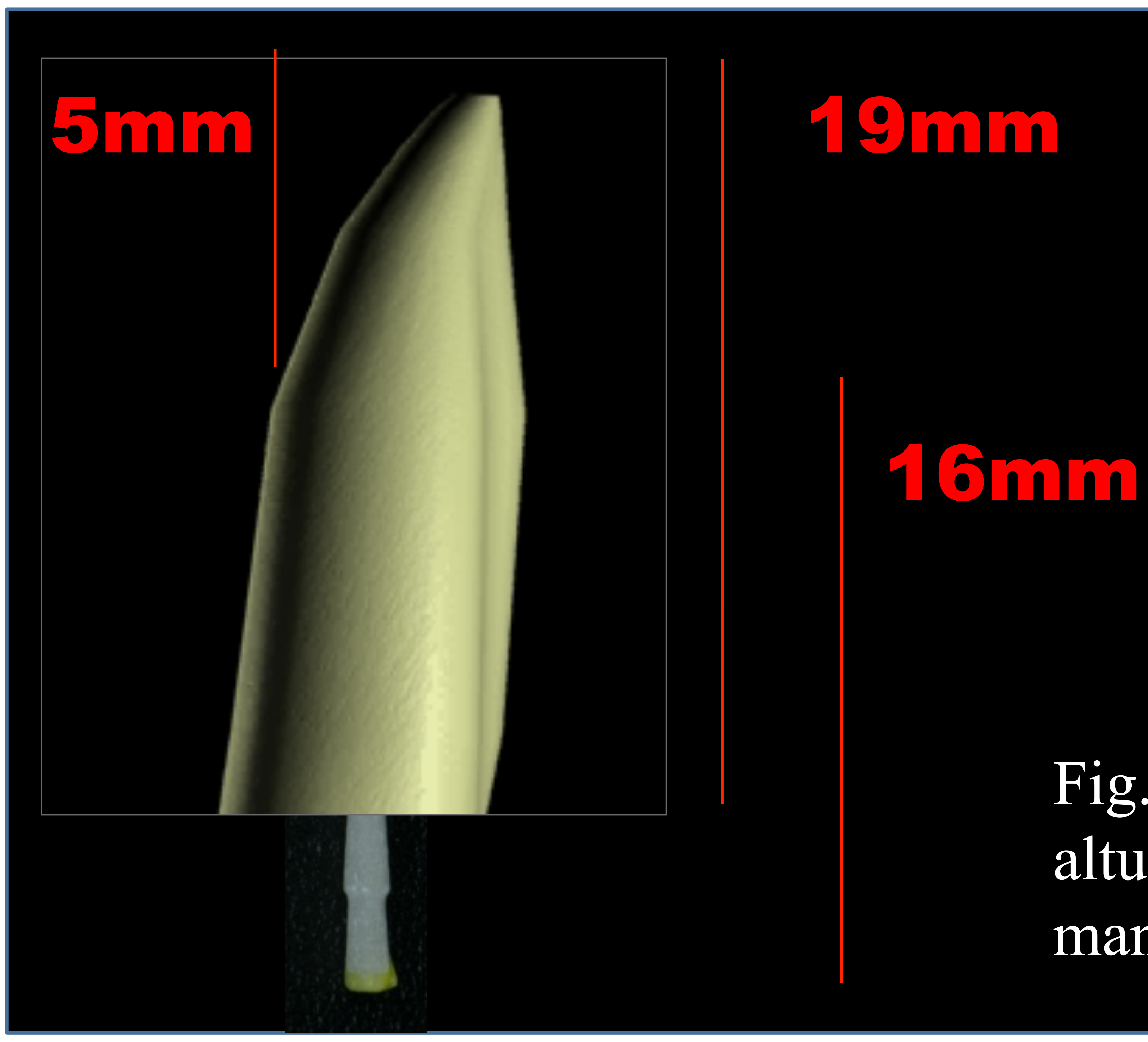


Fig. 2. Raízes padronizadas em 17 mm de altura e condutos radiculares preparados à mantendo 3 mm de guta percha.

Fig. 3**.** Cilindro de PVC para inclusão da raíz, após cimentação do pino, raíz incluída com Resina acrílica e cilíndro de resina acrílica contendo o a raíz e o pino após remoção do PVC

Fig. 4**.** Maquina de cortes precisos utilizada Isomet 1000 Buehler, para o corte das raízes e dos ...

Fig. 5. …cilíndros de resina acrílica …

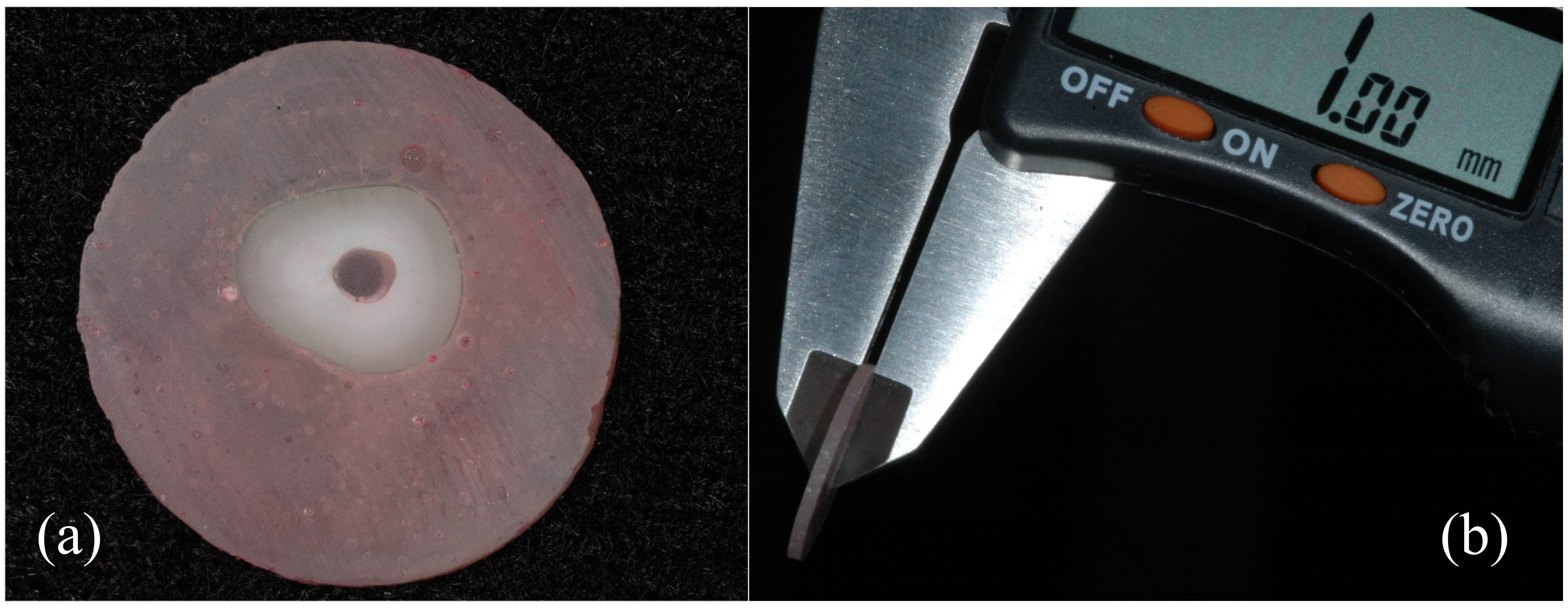


Fig. 6 (a) e (b). … de modo a obter discos com 1 mm de altura.

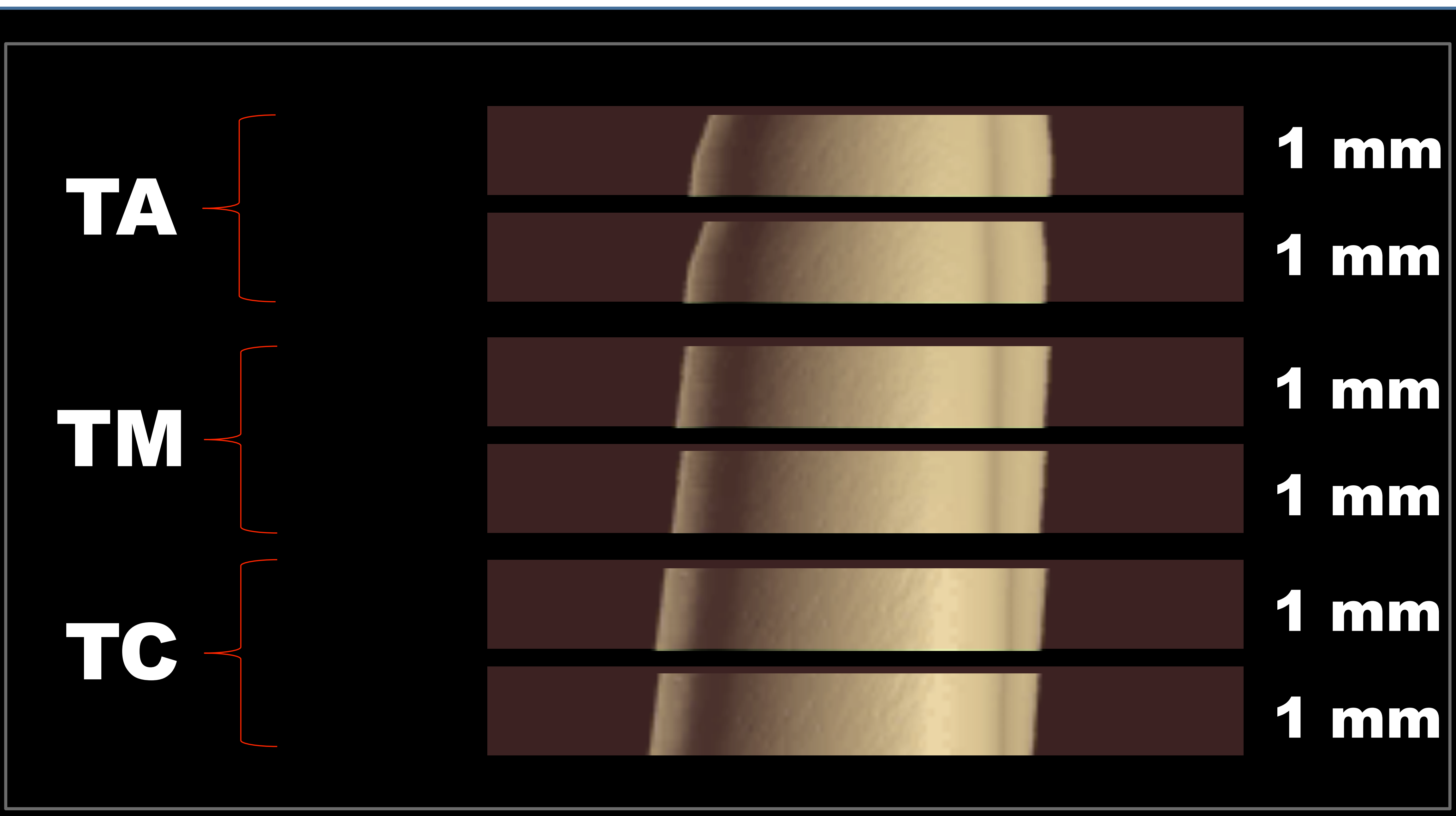


Fig. 7. Foram obtidos 2 discos de 1mm de altura cada, de cada um dos 3 terços.

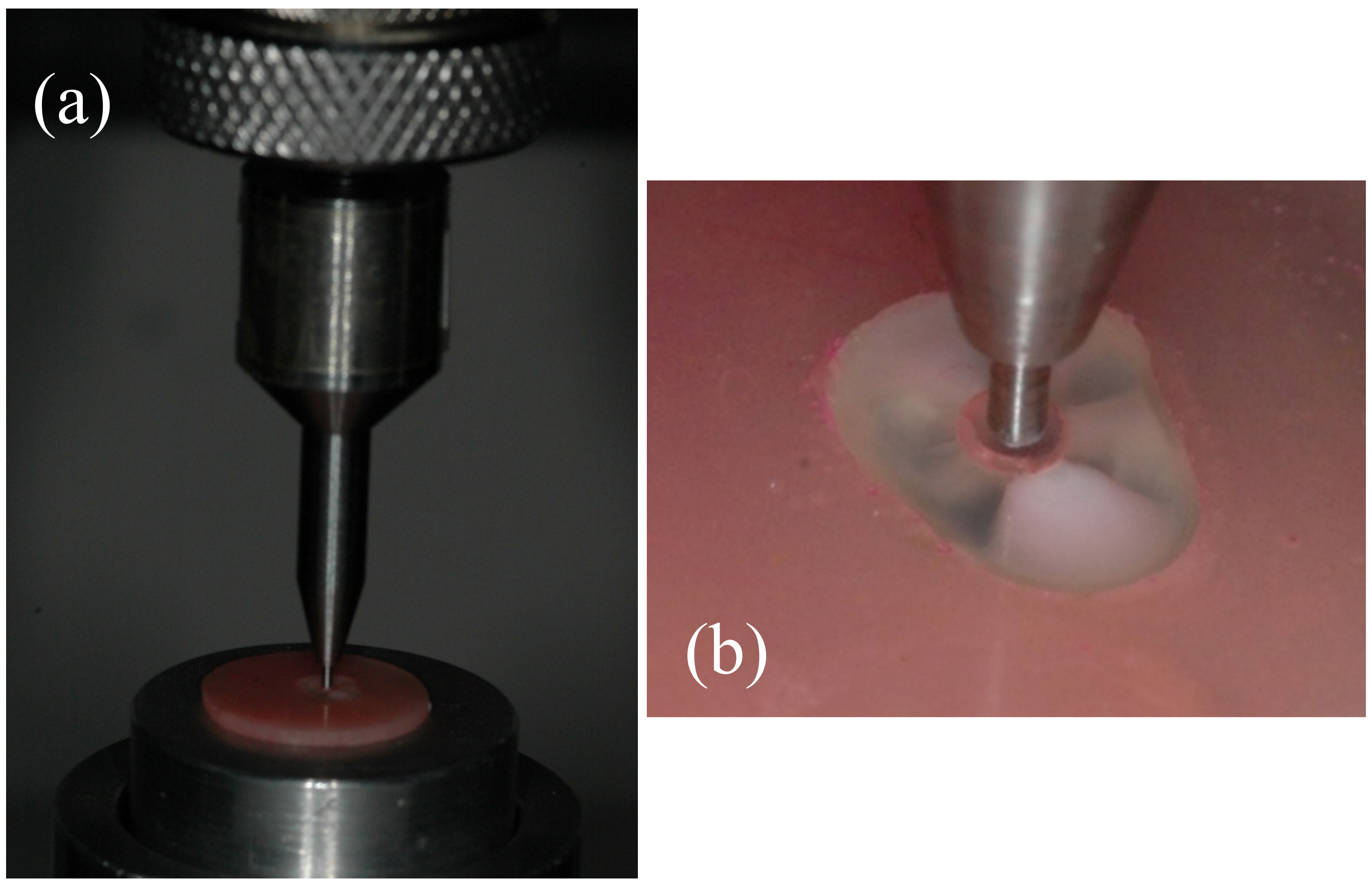


Fig. 8(a). Célula de carga da máquina de ensaios universal. (b) pormenor da célula de carga sobre o pino.

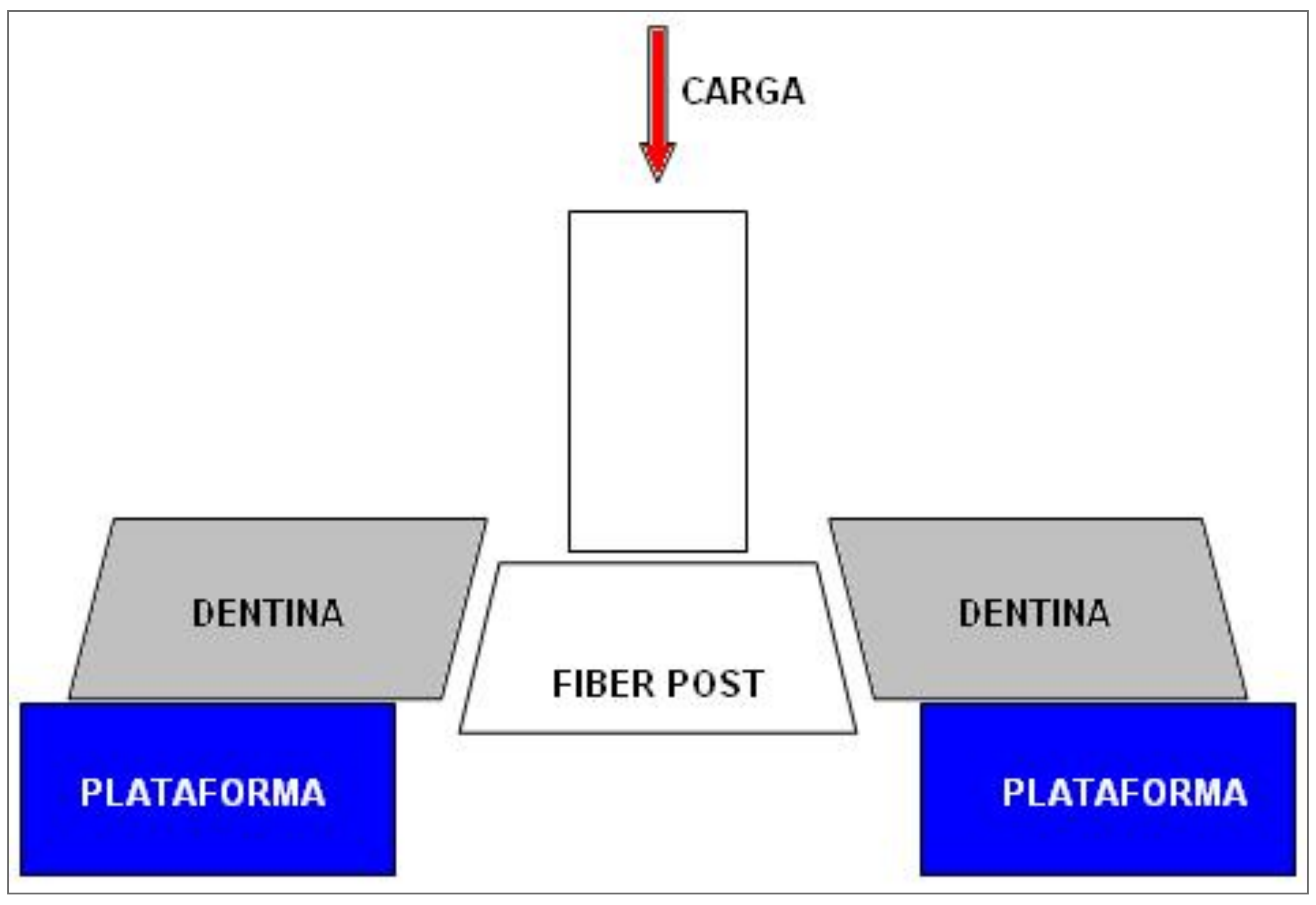


Fig. 9. Ilustração da relação das estruturas do corpo-de-prova com a máquina de ensaios universal.

6. GRÁFICOS

Gráfico 1: Quantidade de energia luminosa transmitida radialmente aos pinos (microwatt/cm^2).

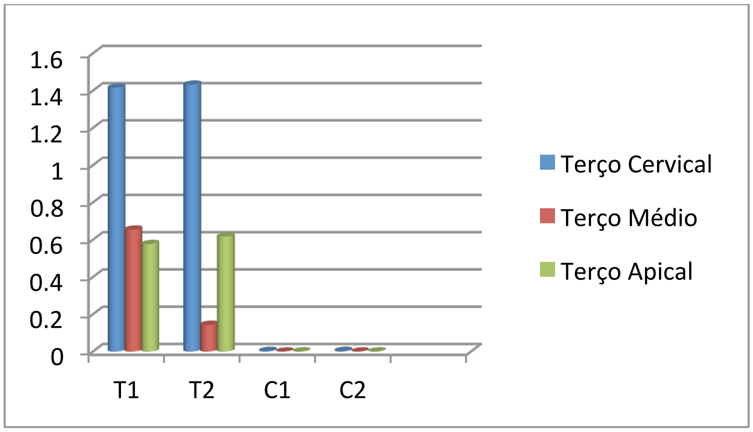


Gráfico 2: Influência da energia luminosa transmitida radialmente aos pinos na microdureza Knoop (KHN) nos grupos teste e cont.

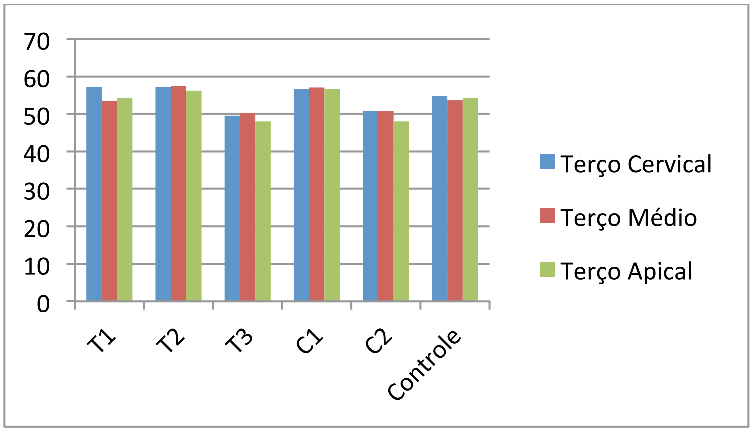
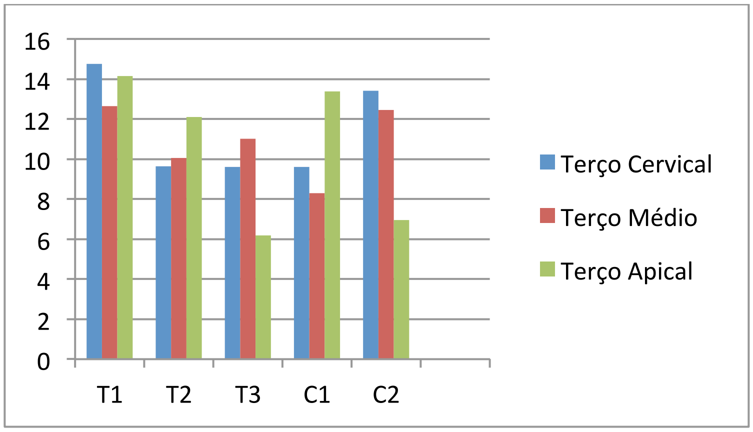


Gráfico 3: Influência da energia luminosa transmitida radialmente aos pinos na resistência adesiva (RA) (Mpa).



7 - CONSIDERAÇÕES FINAIS

Em concordância ao trabalho de Naumann et al., 2008, que consideranda as características mecânicas dos materiais para cimentação, os do tipo resinosos parecem realmente ser a melhor opção para cimentação de pinos intrarradiculares. Entretanto, a escolha destes cimentos quanto ao método de polimerização deve ser pautada nas limitações de transmissão de luz através dos pinos translucentes (Morgan et al., 2008, Ho Y et al., 2011) e, portanto, seu acesso às regiões mais profundas do espaço do pino no conduto radicular.

O objetivo deste estudo foi investigar e estabelecer uma relação precisa da quantidade de luz transmitida através de pinos de fibra e seu efeito na KHN e na RA de um cimento resinoso de dupla polimerização. Nossos resultados mostram boas evidências de que a quantidade de luz tranamitida é baixa e não tem influência na retenção do pino ao conduto radicular ou na microdureza do cimento resinoso dual auto-adesivo utilizado.

Em face aos nossos achados não recomendamos utilizar cimentos fotopolimerizáveis ou de dupla polimerização. Pelas razões discutidas nossa recomendação é de que até o surgimento de novas evidências científicas apenas materiais auto-polimerizáveis sejam utilizados. Importante salientar que não estamos contra-indicando os pinos translucentes. Estes pinos tem características mecânicas semelhantes aos outros fibroresinosos. Só não recomendamos seu uso associado a cimentos que dependam da luz no seu processo de polimerização.

A utilização de cimentos resinosos auto-adesivos de dupla polimerização deve ser discutida à parte. O uso desses cimentos traz vantagens baseadas na diminuição de passos clínicos, facilidade técnica, diminuição da possibilidade de erros e do tempo clínico gasto nos dos procedimentos de cimentação. Em recente estudo pode-se verificar que em algumas situações clínicas valores de resistência adesiva foram superiores para pinos cimentados com um cimento auto-adesivo comparativamente aos cimentados pela técnica adesiva convencional independente do tipo do cimento quanto à reação química (Mongruel et al., 2012), e a justificativa para tais achados é exatamente pelo fato da simplicidade da técnica. Sendo assim, o uso do cimento auto-adesivo utilizado em nosso trabalho parece ser eficiente na cimentação de pinos intrarradiculares desde que, assim como em qualquer cimentação, os conceitos que regem estes procedimentos sejam fielmente atendidos.

Não obstante a toda essa discussão técnico-científica, o fator preponderante na retenção de um pino continua a ser a retenção friccional. Uma boa adaptação do pino continua sendo primordial para o sucesso restaurador. A função do cimento é tão somente preencher os espaços entre o pino e o canal radicular favorecendo a retenção friccional. Lembrando por fim que nenhum cimento tem a capacidade de compensar preparos intrarradiculares em comprimento inadequado ou um pino mal adaptado (Summitt at al., 2001).

8 – ANEXOS

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM EXPERIMENTAÇÃO ANIMAL
-CETEA-

CERTIFICADO

Certificamos que o **Protocolo nº 19/2010**, relativo ao projeto intitulado "***Influência da transmissão de luz através de pinos de fibra no grau de conversão de resistência adesiva de cimentos resinosos***", que tem como responsável(is) **Luiz Thadeu de Abreu Poletto** , está(ão) de acordo com os Princípios Éticos da Experimentação Animal, adotados pelo ***Comitê de Ética em Experimentação Animal* (CETEA/UFMG)**, tendo sido aprovado na reunião de **28/ 04/2010.**

Este certificado expira-se em **28/ 04/ 2015.**

CERTIFICATE

We hereby certify that the **Protocol nº 19/2010**, related to the project entitled "***Influence of light transmission through fiber posts in the degree of conversion and bond strengh of resin cements***", under the supervisiors of **Luiz Thadeu de Abreu Poletto**, is in agreement with the Ethical Principles in Animal Experimentation, adopted by the ***Ethics Committee in Animal Experimentation* (CETEA/UFMG)**, and was approved in **April 28, 2010.**

This certificate expires in **April 28, 2015.**

Belo Horizonte, 8 de Julho de 2010.

Profª. Jacqueline Isaura Alvarez-Leite
Coordenadora do CETEA/UFMG

Universidade Federal de Minas Gerais
Avenida Antônio Carlos, 6627 – Campus Pampulha
Unidade Administrativa II – 2º Andar, Sala 2005
31270-901 - Belo Horizonte, MG - Brasil
Telefone: (31) 3499-4516
www.ufmg.br/bioetica/cetea - cetea@prpq.ufmg.br

(Mod.Cert. v1.0)

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