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Effect of different retentive systems in the retention of implant-retained overdenture

***In vitro* study**

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Effect of different retentive systems in the retention of implant-retained overdenture

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RESUMO

Introdução: Com o intuito de promover a melhoria da qualidade de vida de doentes edêntulos, existem diversas opções terapêuticas, entre elas as sobredentaduras implanto-retidas que requerem sistemas de retenção. O presente trabalho *in vitro* teve como objetivo comparar o efeito de dois sistemas de retenção de sobredentaduras implanto-retidas: K-Lock (Klockner®, Barcelona, Spain) e Locator® (Zest Dental Solutions, California, USA), simulando 12 meses de utilização.

Materiais e métodos: Efetuou-se a caraterização das matrizes em *nylon* para as 3 cores utilizadas no estudo (azul, rosa e transparente), através de ensaios mecânicos sob controlo de carga compreendendo ciclos de compressão da matriz sobre uma superfície metálica plana.

Relativamente aos testes de inserção e de remoção, pré-determinaram-se seis grupos de trabalho (n=5), emparelhando cada sistema de retenção com cada uma das cores das matrizes. Após a instalação dos implantes nos blocos de poliuretano e da respetiva conexão dos sistemas de retenção e matriz, cada um dos grupos foi submetido a 1095 ciclos de inserção/remoção.

Resultados: O modelo reológico de *Kelvin Voigt* revelou que as três cores de matriz têm o mesmo componente K ($5x10^3$ N/mm), mas, relativamente ao componente C as matrizes rosa e transparente apresentaram valores distintos da matriz azul (43, 42 e 32 N/(mm/s), respetivamente). Os valores de retenção aferidos neste estudo são equivalentes aos propostos pela literatura. O Sistema de retenção K-Lock revelou diferenças estatisticamente significativas ($p < 0,05$) entre as forças de inserção e remoção associadas às três cores das matrizes. Entre os dois sistemas de retenção verificaram-se diferenças estatisticamente significativas entre as forças de inserção, aos 270, 540, 810 e 1095 ciclos, associadas à matriz azul e rosa ($p < 0,05$) e entre as forças de remoção, aos mesmos ciclos, associadas à matriz azul ($p < 0,05$).

Conclusão: Verificaram-se diferenças estatisticamente significativas entre os dois sistemas de retenção relativas à inserção para a matriz azul e rosa e à remoção para a matriz azul.

Palavras-chave: sobredentadura, sistema de retenção, implante, pilar, matriz, retenção

ABSTRACT

Introduction: In an attempt to promote the reestablishment of the quality of life of edentulous patients, several therapeutic options arise, such as implant-retained overdentures, which require the use of retention systems. The purpose of this study was to compare the effect of two retention systems: K-Lock (Klockner®, Barcelona, Spain) and Locator® (Zest Dental Solutions, California, USA), on the retention of implant-retained overdentures, over an one-year follow-up period.

Materials and Methods: Firstly, we proceeded to the characterization of a nylon insert of each color used in this in vitro study (blue, pink and clear). For this purpose, mechanical tests were performed under load control, through compression cycles of the nylon on a flat metal surface.

Regarding the insertion and removal (pull out) tests, six working groups (n=5) were predetermined, pairing each retention system with each of the nylon insert colors. After placing the implants in the polyurethane blocks and connecting them to the retention systems and nylon inserts, each group underwent 1095 insertion/removal (pull out) cycles.

Results: The rheological model of *Kelvin Voigt* showed that the three colors had the same component *K* (5×10^3 N/mm), but, regarding the component C, pink and clear nylons presented different values from the blue nylon insert (43, 42 and 32 N/(mm/s), respectively). The retention values measured in this study were equivalent to those proposed in the literature. K-Lock system showed statistically significant differences between the three colors of nylon in insertion and remotion ($p < 0{,}05$). Between the two retention systems it was found a statistically significant difference between the insertion forces at 270, 540, 810 and 1095 cycles associated with blue and pink nylon ($p < 0{,}05$) and between the removal (pull out) forces associated with the blue nylon at 270, 540, 810 and 1095 cycles ($p < 0{,}05$).

Conclusions: Statistically significant differences were revealed between the two retention systems regarding insertion for blue and pink nylon inserts and regarding removal (pull out) for blue nylon insert.

Keywords: overdenture, retention system, implant, abutment, nylon insert, retention

INTRODUCTION

Nowadays we can observe a global demographic aging. According to 2021 Portugal's demographic statistics yearbook, between 2011 and 2021, Portugal registered an increase in the elderly population, so that in 2021 those aged 65 or over, represented 23,4%. Health authorities emphasize the problem corresponding to certain modifiable risk factors common to chronic pathologies and injuries associated with aging, including oral diseases. As result, there is a growing prevalence of edentulism that leads to a progressive need for complete oral rehabilitation in order to reestablish the quality of life of these patients.[1]

If the increase in average life expectancy is not accompanied by the promotion of quality of life, for example, better health care, there will be direct negative repercussions that will affect public health in developed countries[1]. Therefore, this reality requires efforts to be made to achieve better care in the field of oral rehabilitation, whether partial or total, in order to reestablish the quality of life of these patients.

In the field of oral rehabilitation, revolutionary developments emerged, around 1980 and 1990 with the introduction of dental implants in clinical practice. Thanks to this feat, several limitations of the removable prosthesis, as stability and retention's deficit, can be controlled or greatly reduced. In situations of completely mandibular edentulism, the "standard" treatment choice is a two implant retained overdenture.[2]

It is clear that patients' adherence, adaptation and commitment regarding rehabilitation with conventional removable dentures is lower in comparison to implant-supported fixed rehabilitation or even implant-retained removable dentures.[3-6] In fact, these patients also refer that complete fixed rehabilitations are associated with higher masticatory performance, bite force, and nutritional state. Sharma et al found that implant overdentures had 25% better chewing efficiency and twice the bite force when compared to conventional dentures.[7]

The elements that establish the connection between the implant and the prosthesis are the abutments, which are available on the market in different designs and sizes.[7] It is known that these connections help reduce the denture movement without adding stress on the implants, or decreasing their wearness.[8]

In between matrix and patrix abutment's components, which are responsible for the retentive force of the attachments, there is a retentive element material. It can be composed of nylon, polyetheretherketone (PEEK) and polyvinylsiloxane (PVS).[4]

The retention systems can be independent/single (like magnetic attachments, spherical attachments, Locator, external resilient attachments – ERA's, Equator) or splinted (connecting bars or frameworks like Dolder and Hader).[9]

Recently, a new retention system, K-Lock (Klockner®, Barcelona, Spain) was developed. It has a cylindrical shape, similar to Locator, but a lower cost.

The literature may help clarify some questions about what systems are more appropriate for certain clinical situations. However, some of these aspects are still not clarified, such as what is the adequate retention force for an attachment system, pointing out that, for a single unsplinted attachment, a minimum force of 4 N is predicted.[3]

Although there are advantages in these therapeutic approaches, changes on retention elements are frequent as a result of attachment abrasion and micromovements during the masticatory process.[10] As the "standard" treatment choice is a two implant retained mandibular overdenture, posterior mastication forces cause rotation of the prosthesis, attachment's movements[10], and consequently it's wearness.

The fact that overdentures are highly frequent in senior patients, who often lack sufficient strength and/or manual dexterity to counteract high retention forces from attachment systems should also be taken in to account.

With this in mind, because of the variety of systems and respective characteristics, it can be difficult to select the best option for each clinical case. According to the literature, the major determinants of success for complete dentures are retention and stability[11], expecting, from the beginning, that, the amount of retention lost over time is important to provide a correct treatment and maintenance plan, depending on the retention system chosen.

The main objective of this study is to determine if there is compatibility between two retention systems K-Lock and Locator®. With that purpose, the two were compared, based on the overdenture's retention loss associated with the insertion and removal (pull out), three times a day, for a period of 12 months.

MATERIALS AND METHODS

Study design

Initially, the nylon inserts used (blue, pink and clear) were mechanical characterized in order to determine its relative mechanical behavior.

To compare the performance of the different retention systems, were included in the study: 3 solid rigid polyurethane foam blocks (used 2 times each: once in each base), 6 tissue level implants – Klockner® Cone Essential 3,5x12 mm, 3 Locator abutments, 3 K-Lock abutments and finally pink, blue and clear nylon inserts of each system.

Each "*abutment and nylon insert"* set was submitted to 1095 insertion and removal (pull out) cycles, corresponding this number to the insertion and removal (pull out) of the overdenture 3 times a day, during 1 year, for oral hygiene.

After submitting each set to the final number of cycles, two graphics were obtained: *load vs number* of cycles and *load vs time*.

In the end, the extrapolated results allowed the comparison of the mechanical performance, that is, the retention force of the two retention systems as well as the respective loss of retention force over the cycles.

Experimental protocol

The implants and abutments were attached to the blocks, thus dividing them into 6 groups (n=5):

- **Group A**: "K-Lock blue" (KB) with the retentive system K-lock and blue nylon insert
- **Group B**: "K-Lock pink" (KP) with the retentive system K-lock and pink nylon insert
- **Group C**: "K-Lock clear" (KB) with the retentive system K-lock and clear nylon insert
- **Group D**: "Locator blue" (LB) with the retentive system Locator and blue nylon insert
- **Group E**: "Locator Pink" (LP) with the retentive system Locator and pink nylon insert
- **Group F:** "Locator clear" (LT) with the retentive system Locator and clear nylon insert

All groups were submitted to 1095 insertion and removal (pull out) cycles, 5 times and between each of them, was changed de nylon insert.

1. Materials

1.1. Testing machine

To simulate the insertion and removal (pull out) movements a dynamic and fatigue testing system: an Instron servo-electric machine model ElectroPuls E10000 was used (Fig.1A).

1.2. Polyurethane block

To simulate the cortical bone, a solid rigid polyurethane foam (Sawbones®, Malmö, Sweden) was used (Fig.1B) for this biomechanical testing of insertion and pull out motion. The original measures were 130 mm x 180 mm x 40 mm and after dividing it into three, we obtained geometrically equal blocks with 130 mm x 32 mm x 40 mm. Then, to fix the block to the testing machine, two holes were made.

Then, an implant tissue level, Cone essential – Klockner®, 3,5 mm x 12 mm, was inserted, in a perpendicular position, at the central point of one of the bases of each block. Implant placement was performed at a speed of 800 rpm and torque of 40 N×cm. After implant insertion, an abutment (Locator® and K-Lock) was connected onto it, with the help of a dynamometric wrench, with a torque force of a 20 N×cm. This abutment will later, be in touch with the nylon insert of each color (blue, pink and clear), these elements constituting the assembled set (Fig.1C).

1.3. Milled piece for characterization

The nylon inserts characterization involved the production of a metallic piece (Fig. 1D) with a round lower end that had a diameter corresponding to the inner surface of the nylon insert and the upper end allowed its adaptation and gripping by the movable arm of the testing machine.

1.4. Housing/Matrix housing

In general terms, each retention system has 3 components: a metal matrix housing, a retention nylon device of the female part and male part (patrix) (Fig. 1E). In this study, the matrix housing was joined to the “T” milled piece (Fig. 1F), allowing, with help of machine’s moving arm, insertion and removal (pull out) of the female part.

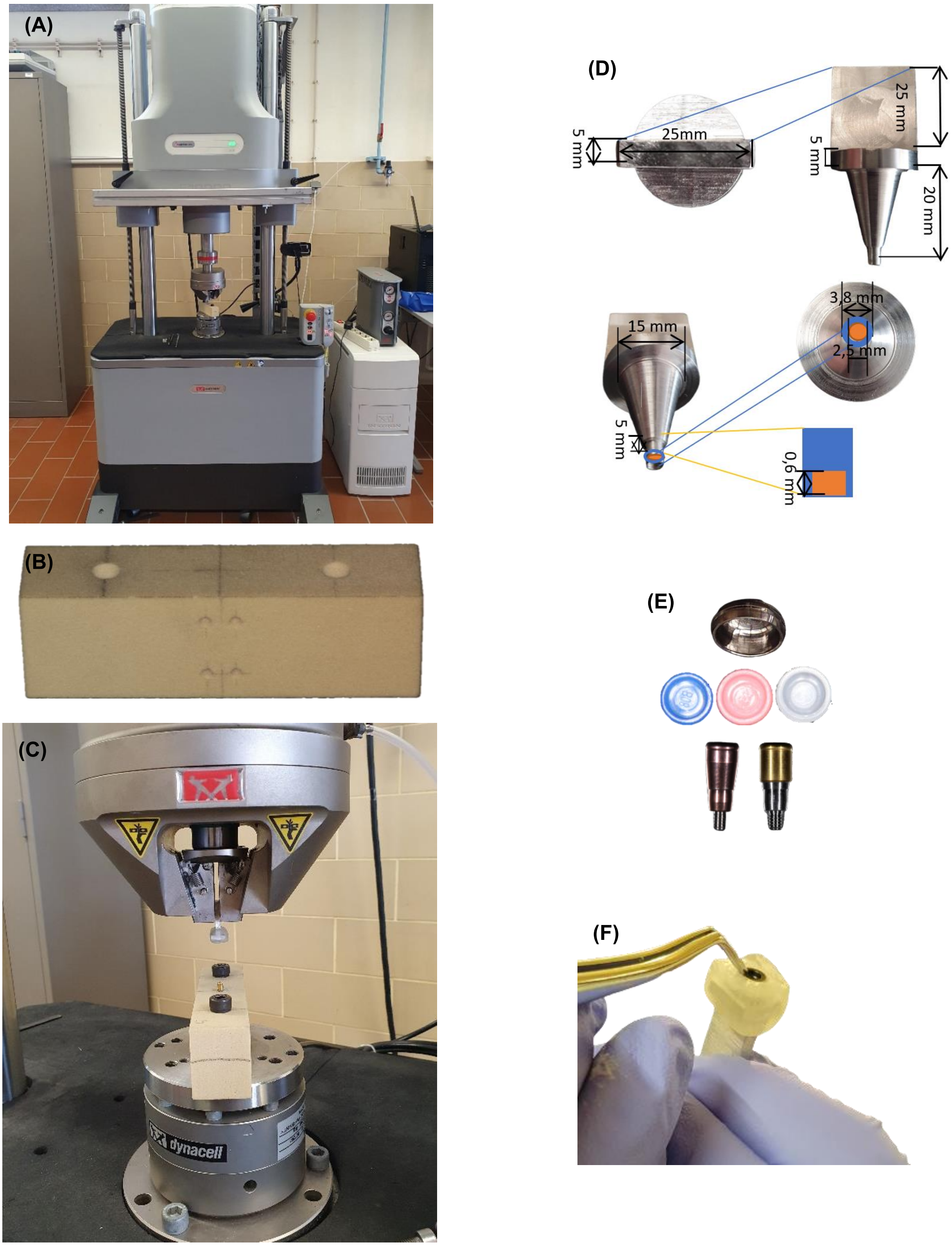

Figure 1: (A) Testing machine**. (B)** Polyurethane block. **(C)** Fixed project set: on top, the "T" milled piece with matrix housing of female part, retention device of female part; at the base of the set, the block with implant and Locator® pilar. **(D)** Milled piece for characterization. **(E)** On top matrix housing of female part; in the middle nylon inserts of female part; below K-lock and Locator® male part (patrix). **(F)** Union of the housing to the "T"milled piece by acrylization.

1.5. "T" milled piece

This component allowed to connect the machine to the housing, enabling a uniform load transmission throughout the entire structure.

The housing was joined to the "T" milled piece through acrylic additions (Fig.1F), so that the housing was in a central position and parallel to the base of the block.

2. Methods

2.1. Characterization

The characterization was carried out according to a standard that complies with the control of load, through cyclic compression cycles of the nylon insert on a flat metal surface.

A total of 3 nylon inserts were tested (one of each color: blue, pink and clear). The norm used to carry out the characterization tests comprised: medium load of -70 N, amplitude of 50 N, range of values of -120 N to -20 N, 500 cycles and a frequency of 5Hz. Then the rheological model of *Kelvin Voigt* was applied to evaluate the viscoelastic behavior of nylon inserts.

2.2. Insertion and removal (pull out) tests

Then proceeded to the correct assembly of the block and the "T"-milled piece in the testing machine, to start the insertion and removal (pull out) cycles.

2.2.1. Placing the nylon insert in the housing.

2.2.2. Assembly of the set: Block (with pillar) + milled "T" piece (with housing and nylon insert). The latter was mounted in a vertical position and during this assembly the block's fixing screws were not tightened, that is, the block had freedom of movement (limited).

2.2.3. The testing machine's movable arm was moved to the -1mm position (corresponding to the position after insertion).

2.2.4. The position of the "T" milled piece was verified in the plane of symmetry for the position of the machine's movable arm's moorings.

2.2.5. Closure of the mobile arm's moorings.

2.2.6. Machine arm's movement between positions -1 mm and 0 mm, and verification of the occurrence of: Initial load period close to 0, followed by load increase (removal/pull out), peak reaching, followed by a new decrease to value of 0 before settling reach the upper displacement limit (corresponding do 0 mm).

2.2.7. Then, machine’s movable arm was moved downwards; When the -0,3 mm/-0,4mm position was reached, the insertion load begins, and undergoes a progressive increase until reaching the maximum value, followed by a decrease in the load value up to the value 0.

The machine must reach the -1 mm position without a new increase in load, as this would mean that the nylon insert-pillar-housing set would go into compression.

2.2.8. Movable arm repositioning in the 0 mm position and cycles’ start.

2.2.9. A linear displacement was defined to reach the intermediate position and a sinusoidal function, with an amplitude of 0,5 mm, used with a frequency of 1Hz, in which the lower position corresponds to the fully engaged retention system (-1 mm) without external load and the upper position corresponds to the effectively disengaged system (0 mm).

The insertion-removal (pull out) cycles were carried out under position control and the data were acquired concomitantly with the execution of the tests by the software *Instron wave matrix*.

3. Statistical Analysis

Statistical analysis was performed with RStudio 2023.06.0+421 “Mountain Hydrangea” release for Windows.

To analyze the interaction between abutment, color and cycle, a three-way ANOVA test was applied. To analyze the effects of the abutment and color variables, a two-way ANOVA test was applied, which allowed to verify the effect of the two variables in the dependent result variable, insertion/removal (pull out) forces. Shapiro-Wilk test evaluated if data distribution was normal in insertion and removal (pull out) cycles. Levene’s test evaluated the homogeneity of variances in insertion and removal (pull out) data. A *p*-value of 0,05 was considered significant.

RESULTS

Characterization analysis

After submitting the 3 nylon inserts to the cyclic compression cycles on a flat metal surface, the rheological model of *Kelvin Voigt* was considered. This model considers that a body, when submitted to a force, responds through the combination of two behaviors: elastic (*K*) and viscous (*C*) (that is, dissipative). These two components were determined by inverse analysis of the force variation with displacement. The results obtained showed that all of three colors have the same component *K* ($5x10^3$ N/mm). However, the component *C* is different between pink and clear nylon inserts (43 and 42 N/(mm/s), respectively and blue nylon insert, that is quite lower (32 N/(mm/s).

Mechanical insertion/removal (pull out) tests

The three-way ANOVA test concluded that, in insertion and removal (pull out), there was no significant three-way interaction between *abutment*, *color* and *cycle*, F(3.86, 44.38) = 0,333, *p* = 0,848 and F(2.89, 33.18) = 0,724, p=0,540, respectively. The test also concluded that there was interaction between *abutment* and *color*, in insertion and in removal (pull out), F(2.00, 23.00) = 11,684, *p* = 0,000315 and F(2.00, 23.00) = 23,086, *p* = 0,00000317, respectively.

The two way ANOVA test revealed that both in the insertion forces and in the removal (pull out) forces was a significant two-way interaction between *abutment* and *color* for all cycles ($p < 0,05$).

Shapiro-Wilk test concluded that the data distribution was normal in insertion and removal (pull out) cycles for both retention systems ($p > 0,05$).

Levene's test of homogeneity determined that there was homogeneity of variances in insertion and removal (pull out) data ($p > 0,05$).

Concerning to the *main effects of color* it was concluded that, in relation to the insertion forces, there was a statistically significant difference between *blue*, *pink* and *clear* nylon inserts of the *K-lock*® abutment after 270 cycles (*p* = 0.0000323), 540 cycles (*p* = 0,000103), 810 cycles (*p* = 0,0000327) and 1095 cycles (*p* = 0,0000967). Besides that, there was a statistically significant difference between *blue*, *pink* and *clear* nylon inserts of the *Locator*® abutment after 540 cycles (*p* = 0,017).

Regarding removal (pull out) forces we observed that there was a statistically significant difference between *blue*, *pink* and *clear* nylon inserts of K-Lock after 270 cycles (*p* = 0,000378), 540 cycles (p = 0,000445), 810 (p = 0,005) and 1095 cycles (p = 0,0000679) and between the three nylon inserts' colors of the Locator® abutment after 540 cycles (p = 0,01) and after 810 cycles (p = 0.03). In none of the other groups a statistically significant difference between the three colors of nylon inserts was found.

Pairwise comparisons were also made for "*Color*" within each "*abutment*" (Fig.2), and for "*abutment*" within each "*Color*" (Fig.3) for insertion and removal (pull out) forces.

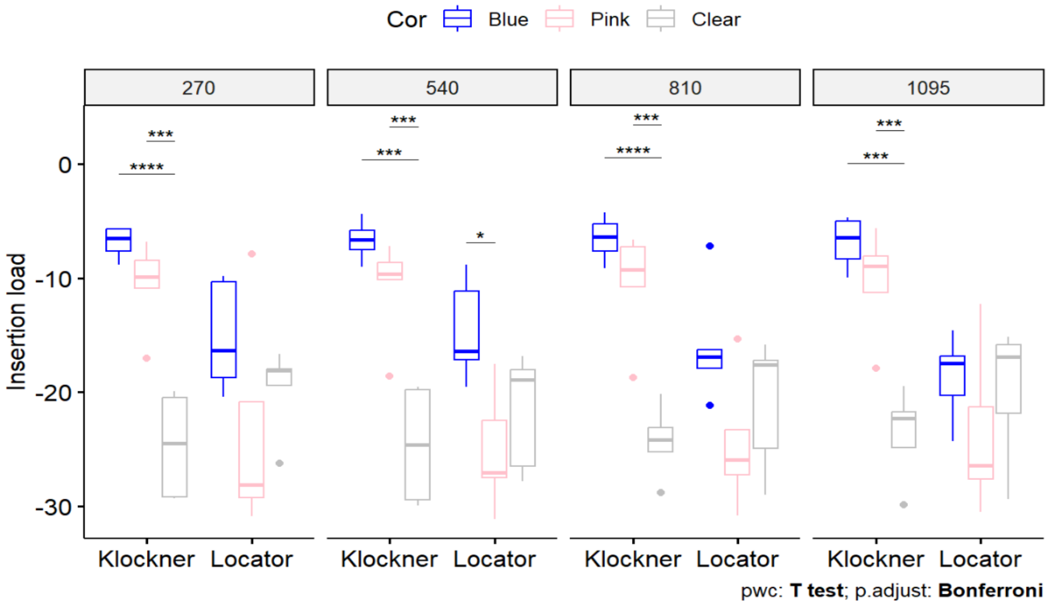

Figure 2(A). Pairwise comparisons for "*Color*" within each "*abutment*" in insertion forces.

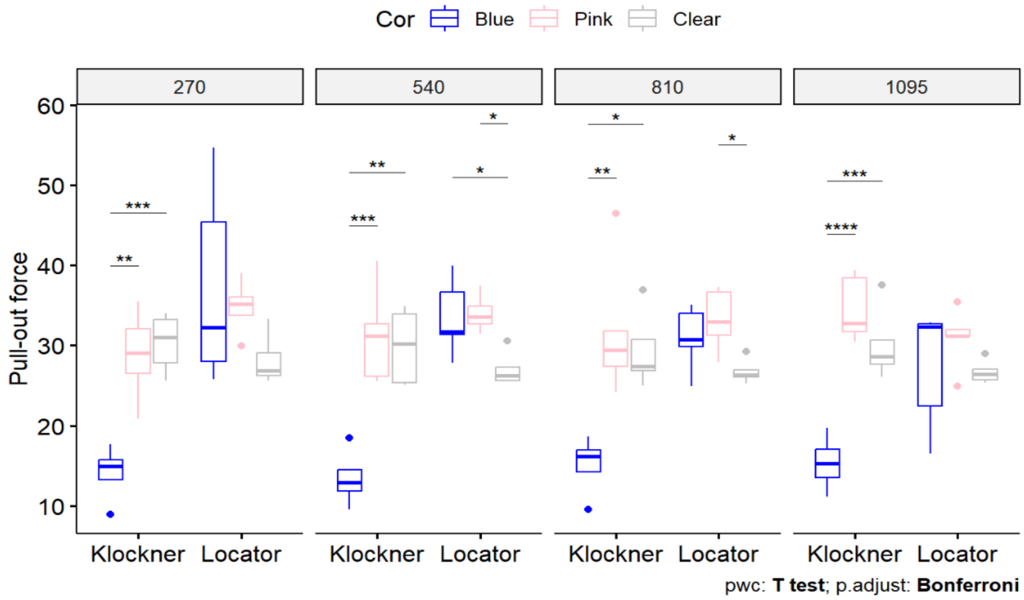

Figure 2(B). Pairwise comparisons for "*Color*" within each "*abutment*" in removal (pull out) forces.

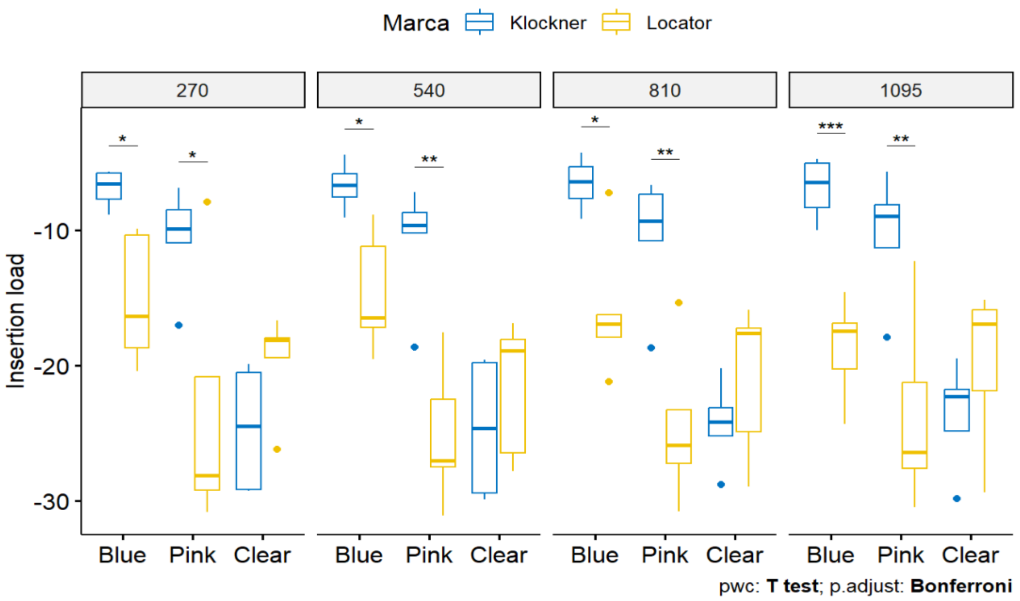

Figure 3(A). Pairwise comparisons for "*abutment*" within each "*Color*" in insertion forces

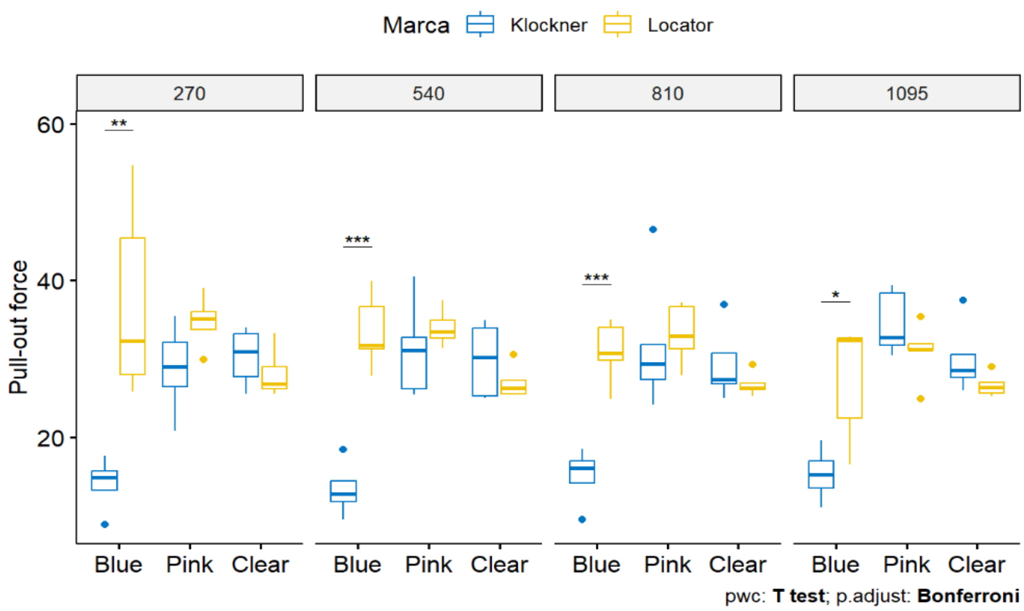

Figure 3(B). Pairwise comparisons for "*abutment*" within each "*Color*" in removal (pull out) forces.

Table 1. Insertion and removal (pull out) mean values of K-Lock and Locator

		K-Lock		Locator	
Cycle	Color	Mean (N)	sd	Mean (N)	sd
		Insertion			
270	Blue	-6,88	1,49	-15,14	4,82
540		-6,68	1,91	-14,63	4,45
810		-6,54	2,09	-13,01	11,47
1095		-6,9	2,46	-18,7	3,73
270	Pink	-10,62	3,89	-23,39	9,47
540		-10,86	4,49	-25,14	5,24
810		-10,54	4,85	-24,53	5,8
1095		-10,38	4,66	-23,61	7,16
270	Clear	-24,67	4,51	-19,68	3,8
540		-24,67	5,01	-21,63	5,11
810		-24,3	3,14	-20,92	5,73
1095		-23,65	3,97	-19,84	5,95
		Remotion			
270	Blue	14,1	3,68	37,24	12,36
540		13,44	3,71	33,48	4,77
810		15,09	3,9	30,92	4
1095		15,34	3,57	27,38	7,49
270	Pink	28,79	5,57	34,79	3,33
540		31,22	6,07	33,99	2,32
810		31,86	8,62	33,23	3,87
1095		34,56	4,09	30,93	3,8
270	Clear	30,31	3,56	28,2	3,13
540		29,89	4,63	27,07	2,08
810		29,4	4,7	26,79	1,52
1095		30,08	4,47	26,68	1,46

DISCUSSION

The current study aimed to compare the effect of two different overdenture retentive systems: K-lock and Locator®, by submitting them to insertion and removal (pull out) cycles equivalent to one year of use, simulated in a dynamic and fatigue testing system: an Instron 10000 servo-electric machine.

Since the retentive behavior is influenced by the nylon insert placed between patrix and matrix retention system components, viscoelastic behavior of each nylon insert color was evaluated.

As Elsyad et al concluded, rheological model of *Kelvin Voigt* application verified that, blue nylon insert is associated to lower initial and final retentive force, and pink and clear nylon inserts shows higher forces.[12]

We also found this aspect in our study, although the dissipative component of the pink and clear nylon inserts was similar, the dissipative component of the blue nylon insert proved to be much lower. This means that when the nylon inserts are subjected to equal force, the blue nylon insert deforms more easily, i.e. the blue nylon insert consumes less chewing energy.

Besides that, after analyzing the geometry and nylon inserts dimensions, it was observed that the internal diameter of nylon insert surface decreases in the following order: blue, pink and, finally, clear matrices. The closer contact between the inner surface of the nylon insert and the abutment surface, created greater friction and, consequently, greater retention force.

After analyzing the extreme outliers by the initial statistical analysis of this study, the group “K-lock blue” after 270 cycles was an extreme outlier. Consequently, a connection was established between the insertion and removal (pull out) force values referring to the outlier, with a positional change of the block on the fixed base of the testing machine to adjust its axiality in the assembled set. Thus, the values related to this series were eliminated, and only four series from the group “K-Lock blue” were considered for the final statistical analysis.

The three-way ANOVA test concluded, in removal (pull out), that there was no significant three-way interaction between *abutment*, *color* and *cycle*, i.e., there wasn’t the presence of main effects of *abutment*, *color* and *cycle*. However, the three-way test concluded that there was a significant two-way interaction between the *abutment and color* variables.

The two-way ANOVA test clarified that the removal (pull out) load was variable according to the combination of *Abutment and Color*.

In general, we can say that the retention values recorded over the removal (pull out) cycles of the two retentive systems (13,4 ± 3,71 N to 34,6 ± 4,09 N) were equal/higher than those suggested by Lehman et al., Pigozzo et al. and Aroso et al., as a minimum retention strength that a stud attachment must have are 4 N, 5 N to 7 N and 5 N to 20 N, respectively [13-16].

Similar to our study, another study that does not refer the use of artificial saliva, indicated the value of 36,74 N as the mean retention force of Locator® with blue nylon insert after 100 pulls.[17] This value is similar to the mean value recorded in our study (at 270 cycles) with the blue nylon insert (37,24 ± 12,345 N).

Stephens et al., measured, the retention force of the Locator with blue nylon insert at 250 cycles, the value 18.63 ± 4,63 N, a lower value than the one observed in our study at 270 cycles (37,24 ± 12,345 N). However, we have to take into account that Stephens et al. added artificial saliva to the assembled set, whereas we did not.[18]

Another study by Aroso C.[16], as in ours, included an assembled set that contemplated only one implant combined with an abutment, during the insertion/removal (pull out) cycles. However, it involved immersion of the assembled set on artificial saliva, leading to much lower retention values than those recorded in our study.

With regard to the manufacturer published data, in the case of the Zest Dental Solutions®, used for the Locator abutment, the following force measurements are indicated for each color: 6,67 N for blue nylon insert, 13,35 N for pink and 22,24 N for clear nylon.[19] In our study we observed that the force measurements of the nylon inserts used were higher.

Contrary to what was expected, after 270 and 1095 cycles there was no statistically significant difference in removal (pull out) forces between the three colors of nylon insert in the Locator® abutment ($p = 0,193$ and $p = 0,372$, respectively).

As we can observe in the graphic representation that shows the effects of the color (Fig.2), in the removal (pull out) movements, the boxes related to each of the colors, in each cycle level, are organized, in general, on a very concentrated level of the boxplot diagrams, instead of, as expected, being arranged in a “ladder” organization, starting with the blue color, at a lower level, moving to a higher level corresponding to the pink color and ending with the clear nylon insert at the top. The absence of this provision may eventually be justified by the superimposition of the effect of (non-)lubrification which would mimic the behavior of the retention system to that observed in an intraoral environment, to the effect of the different color of nylon insert.

Analyzing Table 1, it can be observed that, contrary to what is supported by the literature[20], the clear nylon insert is not associated with higher removal (pull out) forces (29,4 ± 4,7 N to 30,08 ± 4,47 N for K-lock and 26,67 ± 1,45 N to 28,2 ± 3,5 N for Locator®)

In a different way, about the removal (pull out) forces (Fig.3B) it was found that there was only a statistically difference between the brands with the blue nylon insert after 270 (p = 0,009), 540 (p = 0,000237), 810 (p = 0,000569) and 1095 cycles (p = 0,022).

Compared to *K*-Lock, Locator® abutment presented significantly higher removal (pull out) values when associated with blue nylon insert, as shown at Table 1.

As verified in the graphics in Figure 2(B), K-Lock was more predictable because, as expected, it revealed statistically significant differences in removal (pull out) force values between the different colors of nylon insert. Although it is shown in Table 1, that in K-lock, removal (pull out) forces associated with clear nylon insert were lower than with pink nylon insert, all other groups referred to this retention system had generally portraying what was initially predicted[19,20], i.e., that a lower force was required to insert/remove in the presence of the blue nylon, a higher force for the pink nylon and an even higher force for the clear nylon.

Regarding the comparative behavior of the two retention systems, they showed statistically significant differences for the blue nylon insert in the removal (pull out), favoring the Locator® abutment, as show the Table 1. All other groups showed removal (pull out) force values with no statistically significant differences.

LIMITATIONS OF THE STUDY

- Absence of lubrification in the groups tested to simulate the intraoral environment

- The retention systems behavior was tested only including insertion and removal (pull out) forces, not considering the masticatory forces exerted by the patient

- Verification of possible non-standardization of nylon insert (within each color)

- Only one implant was used, and the standard for a mandibular overdenture are two

- The placement of the implant in the block was carried out by the human hand without any standardization device, so that the abutments and implants vertical position may not had been exactly the same in all groups

CONCLUSION

Within the limitations of this study, we can conclude the following aspects:

1. As expected, the rheological model of *Kelvin Voigt* shows that, the blue nylon insert has lower retentive force, and pink and clear nylon inserts have higher retentive force.

2. The retention values in this study are equivalent to those proposed in the literature.

3. K-Lock was more predictable and revealed statistically significant differences in insertion and removal (pull out) force values between the different colors of nylon insert.

4. Statistically significant differences were revealed for the blue and pink nylon in the insertion, and for the blue nylon insert in the removal (pull out).

5. Compared to *K*-Lock, Locator® abutment presented significantly higher removal (pull out) values when associated with blue nylon insert.

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