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Five-year study on short posterior dental implants

Estudo de 5 anos sobre implantes dentários curtos posteriores

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ABSTRACT

Background: Short implants allow dental rehabilitation of patients with insufficient bone volume, avoiding reconstructive surgeries and reducing treatment time, morbidity and costs. **Objective:** Considering implant design, surface and prosthetic connection, the hypothesis tested is that short Neodent Titamax WS implants present success rates similar to those of conventional implants, even when used for single crowns. **Material and Methods:** Eighteen patients with posterior edentulism and maximum bone height of 7mm and width of 6mm were selected. Peri-implant bone level, crown/implant ratio and the crown's mesiodistal distance were the quantitative variables studied. Vertical and horizontal peri-implant bone losses were measured up to 5 year-follow up in 4 different periods. **Results:** Of the total 20 implants placed, only 1 was lost due to lack of osseointegration and a success rate over the 5-year follow-up period of 95%. There was no statistically significant association between vertical bone loss and crown/implant ratio (P = 0.530) or mesio-distal width (P = 0.378). **Conclusion:** The short implants studied in this work showed a success rate and vertical peri-implant bone loss greater than or equal to the indexes found for regular implants in the literature. The different proportions of implant length and crown did not have any effect on bone loss. For short implants, morse connect may be favorable. Placement of Neodent WS implants (and similar implants) in an intra-osseous protocol and not at bone level needs further investigation because it might present better results in regard to vertical bone loss over time.

KEYWORDS

Alveolar ridge augmentations; Clinical study; Dental implant; Dental prosthesis; Single-tooth implant.

RESUMO

Contexto: Implantes curtos permitem a reabilitação dentária de pacientes com volume ósseo insuficiente, evitando cirurgias reconstrutivas e reduzindo o tempo de tratamento, a morbidade e os custos. **Objetivo:** Considerando o design do implante, a superfície e a conexão protética, a hipótese testada é que os implantes curtos Neodent Titamax WS apresentam taxas de sucesso semelhantes às dos implantes convencionais, mesmo quando usados para coroas unitárias. **Material e Métodos:** Dezoito pacientes com edentulismo posterior e altura óssea máxima de 7 mm e largura de 6 mm foram selecionados. O nível ósseo peri-implantar, a relação coroa/implante e a distância mesiodistal da coroa foram as variáveis quantitativas estudadas. A perda óssea peri-implantar vertical e horizontal foi medida até 5 anos de acompanhamento em 4 períodos diferentes. **Resultados:** Do total de 20 implantes colocados, apenas 1 foi perdido devido à falta de osseointegração e uma taxa de sucesso ao longo do período de acompanhamento de 5 anos de 95%. Não houve associação estatisticamente significativa entre perda óssea vertical e relação coroa/implante (P = 0,530) ou largura mesiodistal (P = 0,378). **Conclusão:** Os implantes curtos estudados neste trabalho apresentaram taxa de sucesso e perda óssea peri-implantar vertical maiores ou iguais aos índices encontrados para implantes regulares na literatura. As diferentes proporções de comprimento do implante e coroa não tiveram efeito na perda óssea. Para implantes curtos, a conexão Morse pode ser favorável. A colocação de implantes Neodent WS (e implantes similares) em um protocolo intraósseo e não em nível ósseo precisa de mais investigação, pois pode apresentar melhores resultados em relação à perda óssea vertical ao longo do tempo.

PALAVRAS-CHAVE

Aumento de crista alveolar; Estudo clínico; Implante dentário; Prótese dentária; Implante dentário unitário.

INTRODUCTION

Short implants were developed with the aim of expanding the possibilities of oral rehabilitation, especially for patients with unfavorable anatomy, such as those who have insufficient height and bone volume. The posterior region, both in the maxilla and in the mandible, may present anatomical limitations that make it difficult, or even impossible, to place conventional implants without the need for interventions such as bone grafts surgeries or other associated techniques. These limitations are associated to the presence of the mandibular canal and mental foramen on the mandible and the maxillary sinus on the maxilla. The literature is still controversial on the definition of short implants. Most authors consider implants shorter than 10 mm in length to be the case, and most recently, some studies suggest short implants to be from 5 to 7mm length and ultra-short implants to be 4-5mm [1-9].

In order to provide height and width in cases of bone atrophy, several reconstructive surgical techniques are proposed. Some of the proposed reconstructive surgeries involve bone grafts in onlay and inlay techniques, sinus lifting, osteogenic distraction, split crest fracture, guided bone regeneration (GBR) and mandibular canal deviation (also known as inferior alveolar nerve lateralization) [9-16]. Although extensively described in the literature, all these techniques have their own complexity and associated intra or post-operative complications, making difficult to ensure excellent prognosis for them [5,6,9]. In the case of insufficient bone height where reconstructive surgery is aimed to overcome this deficiency, the results are even more discouraging [5-9,11]. In general, these techniques increase the final cost of treatment, prolong the total time for complete oral rehabilitation and represent at least one or more surgical steps increasing morbidity. Also, the risks of complications are increased. Short implants offer a valid method that can alleviate the need for additional surgical bone augmentation [17], reduce treatment time and cost which in turn can increase overall patient satisfaction and treatment acceptance. In fact, many patients abandon treatment with dental implants when it is necessary to undergo previous reconstructive surgery, either because they do not have satisfactory systemic conditions, or because they refuse to undergo more invasive, time-consuming, expensive procedures with complicated postoperative. According to some authors, this fact justifies the use of short implants whenever possible, thus reducing the time, cost and morbidity of the treatment [1,11-15,18,19]. Despite this, the use of short implants requires more experience from the operator, as adequate primary stability is essential [1].

Several studies have shown that some biomechanical characteristics are important for the success of treatments with short implants [17,20,21]. Increasing the diameter of these implants seems to be important to increase mechanical stability as it allows for an increase in the bone/implant contact area [6,8,17]. The implant surface treatment also promotes an increase in the bone/implant contact area and has osteoconductive properties that improve mechanical and biological stability and can reduce the waiting time for osseointegration or even allow for immediate loading [22,23]. Some authors have shown inferior results for short implants compared with conventional implants when they had smooth surfaces [24,25]. However, recent studies from the past decade, have shown improvements in the success rates of short implants when they had surface treatment, comparable to conventional implants [4,11,26].

In treatments with short implants, the crown/implant ratio is apparently unfavorable [16]. This is because vertical bone loss increases the intermaxillary space. Studies have shown that implant treatments can withstand a higher crown/implant ratio than treatments with dentures on teeth [22,27-29]. The type of prosthesis/implant connection is an important factor for the success of short implants [30]. The internal connections allow for greater stability of the prosthesis and a better distribution of occlusal forces on the implants long axis [20,31,32]. It is not a coincidence that the worst results for the use of short implants use external hexagonal connections [24,25,33]. Despite this, the clinical success of short single implants has been well documented [1]. Studies using short implants with internal connections yield more favorable results, without differences in the success rates between short and conventional implants [3,11,34].

Systematic reviews showed similar success rates between short and long implants regardless of design, surface and diameter [2,4,5,8,35]. These authors suggest that short implants should be used as an alternative to long implants in cases where additional previous surgeries are necessary [2,4,5,8,35].

The use of short implants for single cases has been the subject of some clinical studies in recent years and favorable results have been achieved [3]. These works have some characteristics in common, such as the use of implants with treated surfaces and internal conical prosthetic connections.

Based on the presented literature and considering the biomechanical characteristics of the surface and the prosthetic connection, a formulated hypothesis was generated and tested that Titamax WS short implants present success rates similar to those achieved with implants greater than 7mm in length even when used for single crowns. The Titamax WS dental implant is a short, bone-level implant with an internal Morse taper connection and a straight head. It has a cylindrical conical body with a V-shaped thread, is self-tapping, and is indicated for bone types I and II. It is designed for posterior regions of the mandible or maxilla with limited bone height.

MATERIAL AND METHODS

Patient selection

Patient selection began with clinical examination and evaluation of periapical radiographs. When the patient met the desired profile, a tomographic examination of the toothless region was requested to carry out the surgical planning and implant placement. Patients were over 18 years old and had posterior tooth loss, in the molar and/or premolar regions. The following inclusion and exclusion criteria were followed:

Inclusion criteria

- Posterior edentulous areas with bone height between 5 and 7 mm maximum;
- Bone width of at least 6 mm to allow for the use of Titamax WS implants with a minimum diameter of 4 mm;
- Natural antagonistic teeth or fixed prosthesis;
- Alveolar ridge fully healed (at least 4 months from previous dental extraction).

Exclusion criteria

Severe systemic diseases (eg, uncontrolled diabetes and autoimmune diseases);

- Patients undergoing radiotherapy in the past 12 months in the head and neck region;
- Patients undergoing chemotherapy in the last 12 months;
- Presence of local conditions that may compromise the success of the treatment (eg, uncontrolled periodontal disease);
- Non-collaborating patients;
- Patients who use drugs or abuse alcohol;
- Patients who do not sign the informed consent form.

This study was approved by the Research Ethics Committee of the Faculty of Dentistry of Ribeirão Preto/USP (no 2009.1.199.58.3) and each patient received a free and informed consent form that included written explanations about the procedures to be performed and the contact numbers of the responsible researcher.

Twenty Titamax WS implants were installed in 18 patients. Nine implants were installed in the mandible and 11 implants in the maxilla. This number of implants was chosen based on the availability of surgical sites within the sample. These implants have a cylindrical body, a Morse cone prosthetic interface and a double treated surface with oxide blasting and acid subtraction. The "double treated surface with oxide blasting and acid subtraction" refers to a common surface modification method for titanium dental implants known as Sandblasted with Large grit and Acid-etched (SLA). This subtractive technique creates a specific micro-topography designed to enhance osseointegration (the bonding of bone to the implant surface). In oxide basting the titanium surface is first bombarded with large-grit abrasive particles, typically aluminum oxide (Al2O3). Following blasting, the implant is immersed in one or more hot, strong acid solutions [36]. For diagnostic and planning purposes, they were divided into two groups, Titamax WS Cortical and Titamax WS Medular. The first ones have cutting characteristics on the threads and apex and therefore are more suitable for bone types 1 and 2. Titamax WS Medular implants have thread and apex characteristics that promote better locking and stability in predominantly medullary bone.

Surgical protocol

All implants were installed by the same professional, experienced in the surgical area. After terminal infiltrative anesthesia, an incision and total flap folding were performed.

For osteotomy, the drilling sequence protocol indicated in the company catalog and surgical guide was followed. In some situations, this protocol has been altered to achieve the desired locking and primary stability of the WS implant. In situations where it was found low bone density, sub-instrumentation was performed in order to achieve higher stability torque; in others, where the bone was bone density was high and/or very mineralized, the last drill was repeated to decrease the locking torque. Thus, by changing the surgical technique, a minimum installation torque of 20 N/cm and a maximum of 60Ncm was achieved for all cases.

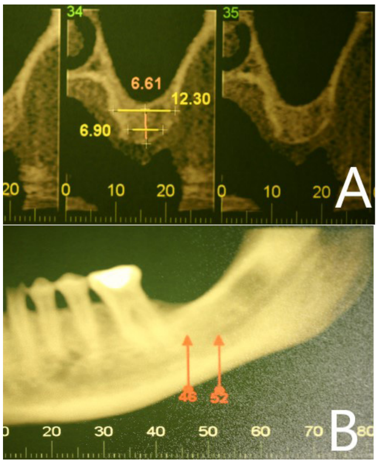

Figure 1 - Initial planning for the surgical through computed tomography. (A) Computed tomography scan of the upper arch and of the lower arch (B).

The drilling speed was 250 RPM (rotation per minute) and the implant setting speed was 25 RPM. In some cases of low-quality bone tissue, manual installation was performed with a surgical torquemeter (Neodent - Curitiba, Brazil/Code 104.027). The final millimeters of the implant placement were achieved with a torquemeter, for measure purposes. After implant placement, selection of the WS Abutment (Neodent - Curitiba, Brazil) was most appropriate for each case using the prosthetic selection components present in the WS Surgical Kit (Neodent - Curitiba, Brazil). The selected WS Abutment was then installed with manual torque so that a periapical radiography could be performed with the radiographic standard guide. This procedure will be better explained in the item "Radiographic evaluations" of peri-implant bone loss. After periapical radiography was taken, the abutment was removed and the cover screw installed (Neodent - Curitiba, Brazil Code 117.016.) for subsequent suturing of the gingival tissue in a 2-step implant placement protocol.

Implants installed in the mandible were reopened after 4 months of waiting for osseointegration and implants installed in the maxilla were reopened after 6 months. This waiting time for osseointegration is accepted as the standard time by the scientific community when immediate load is not used. Some of the surgical steps and initial planning are illustrated in Figures 1 and 2.

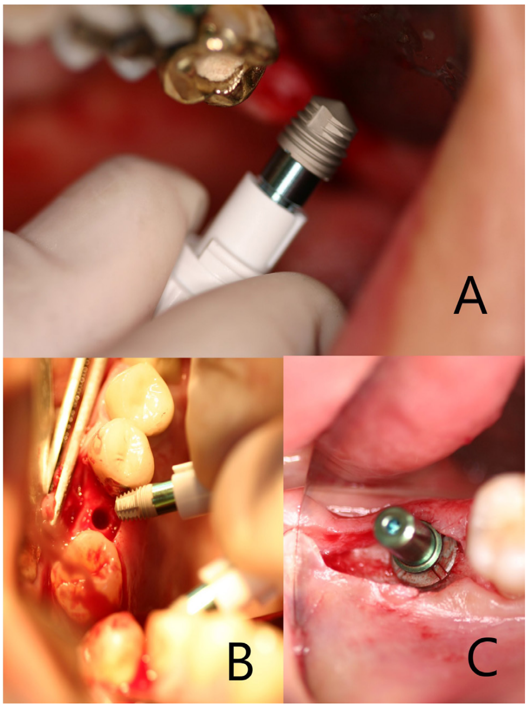

Figure 2 - Surgical steps: (A) Removal of the Titamax WS implant from its sterile packaging and transport to the surgical socket; (B) Implant placement in the previously prepared socket; (C) Selection of the correct prosthetic abutment using a specific selection component.

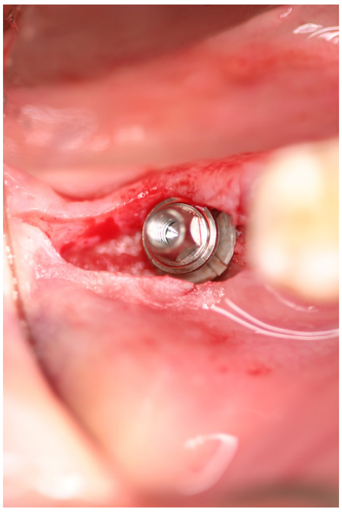

Figure 3 - Abutment installation.

Figure 4 - Abutments installed and tissue healing completed.

Figure 5 - Porcelain adjustments of the tooth 15.

Figure 6 - Porcelain adjustments of the teeth 16 and 26.

Figure 7 - Crowns definitely installed.

Prosthetic protocol

On surgical reopening, the abutments previously selected were installed with the torque of 32 Ncm indicated by the manufacturer (Figure 3). A prosthetic torquemeter was used (Neodent - Curitiba, Brazil/Code: 104.026). These abutments received the protection cylinders (GT/Neodent Protection Cylinder - Curitiba, Brazil/Code: 106.102) during the soft tissue healing, thus enabling the subsequent prosthetic procedures (Figure 4).

Impressions were performed after the peri-implant tissue healing period. In the laboratory, the cast die was made and mounted on a semi-adjustable articulator. The infrastructure was waxed on castable cylinders (GT/Neodent Cylinder - Curitiba, Brazil/Code: 118.180), cast in Nickel-Chrome alloys (Fit Cast-SB Plus/Talmax - Curitiba, Brazil) and then received the porcelain layer (Super Porcelain EX 3/Noritake - Japan) as an aesthetic covering material.

Clinical sessions of infrastructure adjustments followed by porcelain adjustments were carried out (Figures 5 and 6). The crowns were definitely installed after the glazed surface under a torque of 10Ncm (Figure 7). Occlusal tables were reduced to contribute with the occlusal force distribution on the long axis of the implants, and lower cusps were also made.

Data collection

The radiographic measurements of the peri-implant bone level, considering from surgery to 5 year follow-up, the crown/implant ratio and the crown's mesiodistal distance were the quantitative variables studied (Table I).

Radiographic evaluation of peri-implant bone loss

Periapical radiographic evaluations were performed at different periods to monitor possible changes in the bone level or to check for the presence of radiolucent areas around the implants. The first radiograph was taken at implant surgery placement (T1), the second radiograph was taken at the final prosthesis setting (T2), the third radiographic measure was taken after one year with the final prosthesis in function (T3), the fourth radiograph was performed after 3 years of function (T4) and the fifth and final radiographic measure after 5 years of function (T5).

To determine the amount of bone loss for each period, the measurement of the final bone level was subtracted from the measurement of the bone level at the beginning of the evaluated period. The change in bone level was analyzed in four different periods, from the surgical implant placement to the initial prosthesis setting (period 1), immediately after the prosthesis placement to 1 year of function (Period 2), from the initial prosthesis placed to 3 years of function (Period 3) and from the initial prosthesis placed to 5 years of function (period 4) All the radiographic images from the 4 periods can be illustrated in Figures 8A, 8B, 8C and 8D, respectively. In Figure 8D the radiographic image is inverted, but it's possible to see that it's the same patient considering the implant and the adjacent teeth.

Radiographic measures were made using the long cone technique. A personalized radiographic positioner was created to standardize the images. A device was used to connect the long cone and the positioner (Fabinject FPX PADRÃO - Taubate/SP, Brazil), the positioner was modified, and three holes were made in the occlusal support region to connect it to a vertical pin screwed to the abutment[31]. All radiographs were taken on the same X-ray machine.

Table I - Demographic data from all 20 implants installed in 18 patients

Patient Age/Gender	Implant tooth site	Implant size	Total Vertical bone loss	Total Horizontal bone loss	Crown/Implant Ratio	Mesio-Distal Crown width
GCM 54y/F	19	5 × 5 mm	0.33	0	1.9	10
GCM 54y/F	29	5 × 5 mm	-0.84	-0.53	2.1	7.6
IVM 47y/M	14	5 × 6 mm	-1.18	-0.17	2.2	7
JC 55y/M	19	6 × 6 mm	-0.89	-0.25	1.8	6.5
JCS 50y/M	2	5 × 6 mm	-1.02	-0.83	1.6	7
KTQ 27y/F	3	5 × 6 mm	-0.64	0	1.8	9
KSQ 30y/F	14	5 × 6 mm	-1.09	-0.77	1.3	10
MAB 55y/F	18	5 × 6 mm	0.28	0	1.8	8
VAC 55y/F	19	5 × 5 mm	-0.43	-0.04	2.5	8.3
APC 45y/F	18	6 × 6 mm	0.30	0.64	1.7	9.5
APQ 23y/F	13	5 × 6 mm	-0.49	0	1.4	6
EFA 32y/M	13	5 × 6 mm	-0.39	0	1.8	7
KQO 31y/F	20	5 × 6 mm	-0.27	-0.59	1.8	7.5
MAF 60y/F	14	4 × 6 mm	-0.69	0	1.3	5.7
MRR 47y/F	13	5 × 6 mm	-1.21	0	1.4	6
MAP 41y/F	15	5 × 6 mm	-0.44	-0.24	1.8	9
MAG 45y/F	3	5 × 6 mm	-1.25	-0.81	1.5	9
MAG 45y/F	14	5 × 5 mm	-0.69	0	1.9	12
OSS 50y/M	20	5 × 6 mm	-0.45	0	1.6	8
Mean results for evaluated data			-0.58 mm	-0.19 mm	1.73 mm	8.06 mm
Standard Deviation			0.49	0.37	0.31	1.64

Caption: y = Years (age); F = Female; M = Male; mm = millimeters.

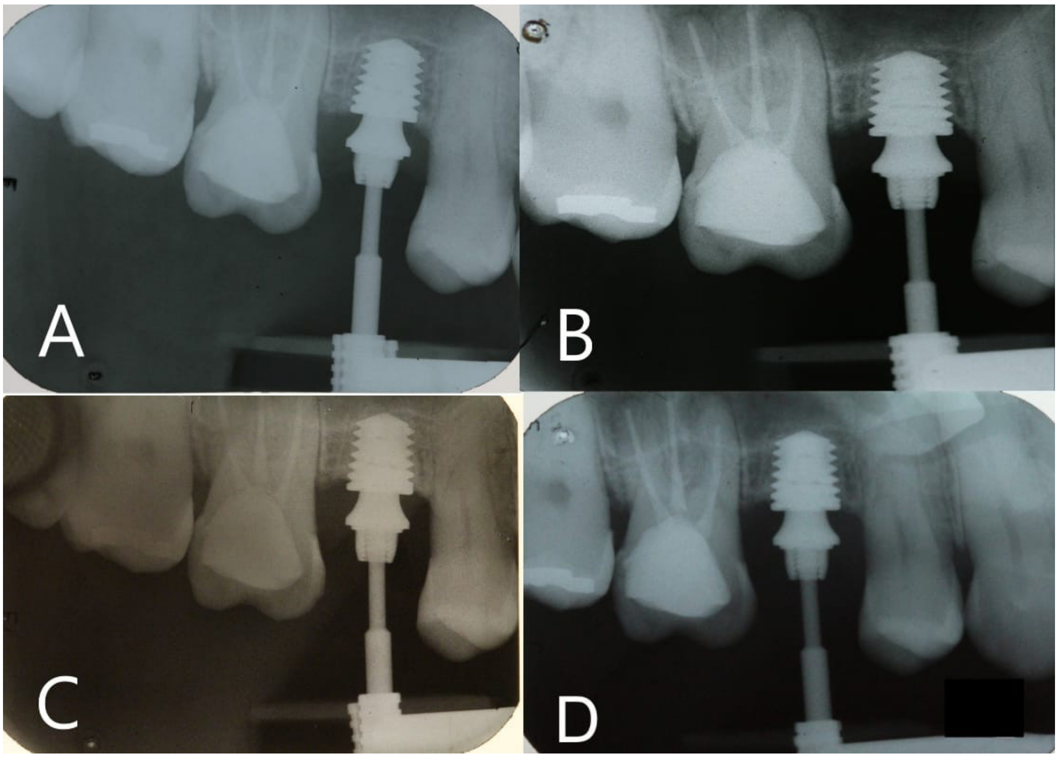

Figure 8 - (A), (B), (C) and (D) radiographic images from the 4 periods, the initial prosthesis setting, 1 year of function, 3 years of function and 5 years of function, respectively.

The digitalized images in JPEG format were opened in the UTHSCSA Image Tool Software (The University of Texas Health Science Center - San Antonio/USA) for vertical and horizontal bone level measurements. First, "calibration" was performed to minimize possible radiographic distortions and generates a measurement with the greater fidelity possible from the real one, which requires knowledge of the measurement. In this work, the implant diameter was used.

For the measurement of the vertical bone level, the distance between the implant platform and the bone crest was considered by drawing a parallel line along the long axis of the implant when the implant was sub-bone. When the implant was supra-bony, a straight line was drawn from the implant platform to the first bone-implant contact point, in this case, the measurements received negative values. This procedure was performed for the mesial and distal regions and an arithmetic mean was then performed between these two values.

For horizontal measurements, a straight line was drawn perpendicular to the long axis of the implants, starting from their platform towards the bone tissue. Negative values were considered when the bone crest moved away from the implant platform. An arithmetic mean was also performed between the mesial and distal measurements to assign a single value of horizontal bone loss per implant in each evaluated period.

Evaluation of the crown-implant ratio and the prosthetic crown mesiodistal width

The dimensions of the prosthetic crown are important data especially when it comes to single implants. To calculate the crown/implant ratio, the sum of the crown height measurement and the height of the "transmucosal neck of the abutment" was considered as a prosthetic lever arm and the mesiodistal width was also verified (Figures 9 and 10).

Statistical analysis

The Linear Regression Test was used to assess the cause-and-effect relationship between the predictive variables (crown/implant ratio, mesio-distal width, crown height) and the dependent variables (vertical bone loss and horizontal bone loss). To assess the difference between bone loss measures in the four studied periods (1, 2 3 and 4), the Analysis of Variance Test (ANOVA) and later Tukey's Test for vertical bone losses and the Kruskal Wallis test for horizontal bone losses. The tests were performed on the SigmaPlot 12.0 Software.

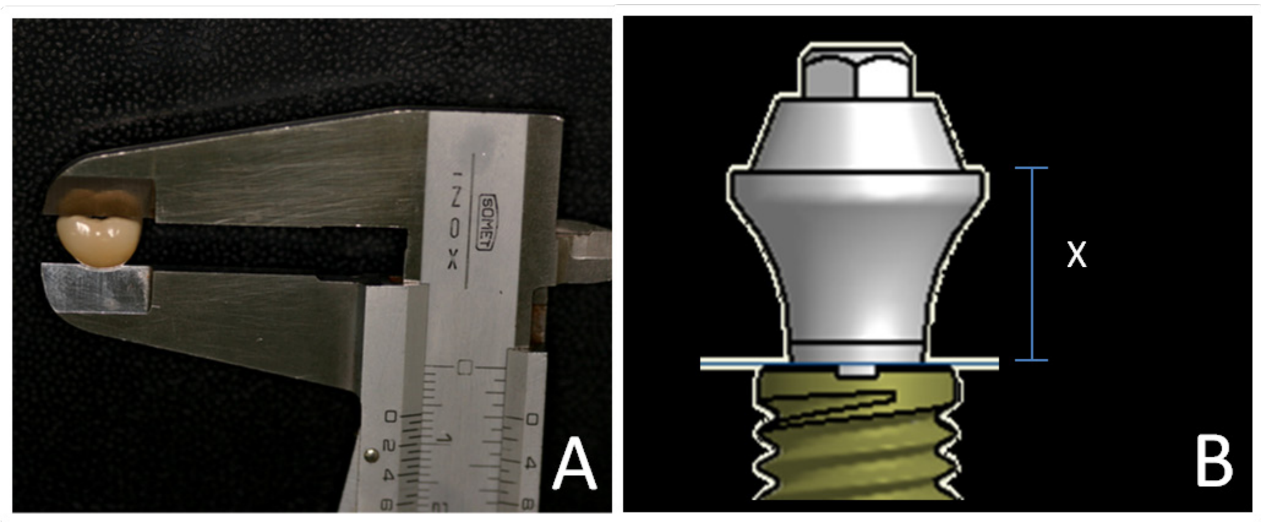

Figure 9 - (A) Measurement of the height of the crown; (B) Measurement the height of the "transmucosal neck of abutment".

RESULTS

A total of 20 implants were placed. Four implants with 5 mm in length and 16 implants with 6 mm in length were installed, whereas 11 where in the maxilla and 09 in the mandible. Only one implant was lost from 20 implants placed. This loss was detected during the reopening surgery. The success rate achieved over the 5-year follow-up period was 95%. The lost implant was in the region of tooth #30, still in the osseointegration phase. The patient who lost this implant had been rehabilitated in two regions, implant #19 and implant #30, both six millimeters long. Table I show all the demographic data of the implants placed.

Radiographic images were used to measure the peri-implant bone level and, consequently, to monitor bone loss or gain of bone in different periods. Negative values indicate supra-bone implants, that is, bone level positioned apically to the platform.

There was no bone gain in any clinical situation, neither vertical nor horizontal. It is worth remembering that the determination of the amount of bone lost for each period was done by subtracting the final bone level measurement from the bone level measurement at the beginning of the evaluated period. The change in bone level was analyzed in four different periods as mentioned in the methodology. Tables II and III show the measures of vertical and horizontal bone loss respectively in the evaluated periods and the bone loss that occurred during the total study period in all diffent evaluated proposed moment.

Figure 10 - Measurement of the mesiodistal width of the crown.

Analysis of variance (ANOVA) showed a statistically significant difference between the periods studied when vertical bone loss was assessed ($P < 0.001$). After that, the Tukey test showed that the statistical difference was found between Period 1 (bone loss that occurred in the post-surgical period and pre-prosthetic loading) with the other periods, 2 ($P = 0.001$), 3 ($P = 0.003$) and 4 ($P = 0.001$). Values of $P < 0.05$ were considered significant.

Table II - Peri-implant Vertical Bone Loss in all periods evaluated, from surgery to 5 year follow-up

		Peri-implant Vertical Bone Loss				
		Period 1	Period 2	Period 3	Period 4	Total period
Patient Age/Gender	Implant tooth site	From surgery to final prosthesis	Prosthesis to 1-year follow-up	Prosthesis to 3-year follow-up	Prosthesis to 5-year follow-up	From surgery to 5 year follow-up
GCM 54y/F	19	-0.24	0.46	0.57	0.57	0.33
GCM 54y/F	29	-0.62	0.06	-0.02	-0.22	-0.84
IVM 47y/M	14	-1.14	0.30	0.53	-0.04	-1.18
JC 55y/M	19	-0.67	-0.70	-0.73	-0.22	-0.89
JCS 50y/M	2	-1.16	0.08	0.24	0.14	-1.02
KTQ 27y/F	3	-0.04	-0.53	0.10	-0.60	-0.64
KSQ 30y/F	14	-0.52	-1.12	-0.98	-0.57	-1.09
MAB 55y/F	18	0.53	-0.60	-0.13	-0.25	0.28
VAC 55y/F	19	-0.6	-0.17	-0.11	0.17	-0.43
APC 45y/F	18	-0.53	0.67	0.67	0.23	0.30
APQ 23y/F	13	-0.14	0.22	-0.49	-0.63	-0.49
EFA 32y/M	13	-1.13	0.37	0.84	0.74	-0.39
KQO 31y/F	20	-0.42	0.23	-1.10	0.69	-0.27
MAF 60y/F	14	-0.61	-0.3	-0.08	-0.08	-0.69
MRR 47y/F	13	-1.17	0.31	0.43	-0.04	-1.21
MAP 41y/F	15	-0.35	-0.28	-0.39	-0.09	-0.44
MAG 45y/F	3	-1.2	0.36	0.09	-0.05	-1.25
MAG 45y/F	14	-0.89	0.39	0.07	0.20	-0.69
OSS 50y/M	20	-0.37	0.16	-0.23	0.08	-0.45
Mean		-0.59	0.00	-0.04	0.00	-0.58
Standard Deviation		0.46	0.47	0.54	0.39	0.49

Caption: y = Years (age); F = Female; M = Male.

Table III - Peri-implant Horizontal Bone Loss in all periods evaluated, from surgery to 5 year follow-up

		Peri-implant Horizontal Bone Loss				
		Period 1	Period 2	Period 3	Period 4	Total period
Patient Age/Gender	Implant tooth site	From surgery to final prosthesis	Prosthesis to 1-year follow-up	Prosthesis to 3-year follow-up	Prosthesis to 5-year follow-up	From surgery to 5 year follow-up
GCM 54y/F	19	0	0	0.00	0	0.00
GCM 54y/F	29	0	0	0.00	-0.53	-0.53
IVM 47y/M	14	0	0	0.00	-0.17	-0.17
JC 55y/M	19	0	0	-0.83	-0.25	-0.25
JCS 50y/M	2	-1.26	0.63	-1.26	0.43	-0.83
KTQ 27y/F	3	0	0	0.00	0	0.00
KSQ 30y/F	14	-0.44	-0.22	-0.33	-0.33	-0.77
MAB 55y/F	18	0	0	0.00	0	0.00
VAC 55y/F	19	-0.58	-0.29	-0.16	0.54	-0.04
APC 45y/F	18	0	0	0.00	0.64	0.64
APQ 23y/F	13	0	0	0.00	0	0
EFA 32y/M	13	-1.27	1.06	1.27	1.27	0
KQO 31y/F	20	-0.67	0.05	0.12	0.08	-0.59
MAF 60y/F	14	0	-0.36	0.00	0	0
MRR 47y/F	13	-0.29	0.11	0.04	-0.29	0
MAP 41y/F	15	0	0	-0.14	-0.24	-0.24
MAG 45y/F	3	-1.15	0.36	0.51	-0.34	-0.81
MAG 45y/F	14	0	0	0.00	0	0
OSS 50y/M	20	-0.54	-0.37	-0.03	0.54	0
Mean		-0.33	0.05	-0.04	0.07	-0.19
Standard Deviation		0.46	0.33	0.49	0.44	0.37

Caption: y = Years (age); F = Female; M = Male.

The Kruskal Wallis test showed that there was no statistically significant difference when comparing the four periods of horizontal bone loss (P = 0.084). This test is used when there is no normal distribution of the studied values. A significance level of 0.05 was considered.

Data on prosthetic parameters, such as mesio-distal crown width and crown/implant ratio, were also collected. The mesio-distal width varied from 5.7 mm to 12 mm. The crown/implant ratio in all cases was greater than or equal to 1.3 with an average of 1.73 (SD = 0.31). It is worth remembering that to determine the prosthetic lever arm, the sum of the crown height and the height of the transmucosal "neck" of the abutment were used. The Linear Regression test showed that there was no statistically significant association between vertical bone loss and crown/implant ratio (P = 0.530) or mesio-distal width (P = 0.378). Besides, there was no statistically significant association between horizontal bone loss with crown/implant ratio (P = 0.591) or mesio-distal width (P = 0.968). In other words, there was no cause and effect relationship between any of these variables at a significance level of 0.05.

DISCUSSION

The success rate achieved in our study over the 5-year follow-up period was 95%. Only one did not osseointegrate despite being installed by the same professional, in the same clinical session and presenting identical bone characteristics, both had type I bone, highly corticalized. The patient who lost this implant had been rehabilitated in two regions, implant #19 and implant #30, both six millimeters long. For this reason, implants with cutting characteristics on the threads and at the apex (Titamax WS Cortical) were used. We hypothesize that the probable reason for non-osseointegration was the lack of adequate blood supply to promote bone repair, characteristic of this type of bone and intensified when implants are installed with high torques [10].

Although the clinical success of short single implants is well documented, the literature is still controversial about the success rates of these implants, probably because there are many variables involved and that operate significantly on these indexes, such as bone type, implant surface treatment type, prosthetic connection type, surgical technique used, types of prostheses (single or multiple), diameter and what each author defines as being a short implant [1-9]. Despite this, the results found in the present study demonstrated high success rates of short implants in the group studied, fill gaps and resolve controversies surrounding the success rates of this type of implant.

Surface treatment seems to be one of the characteristics that most influence the success of short implants [4,5,7,37]. The implants studied in this work have a surface treated with oxide blasting and acid subtraction. The vast majority of studies that showed favorable indexes for short implants used implants with surface treatment [3,4,11,22,26]. The justification would be the fact that the surface treatment increases the area of bone-implant contact, which consequently increases the values removal torque, an important feature for long-term success. Most studies that showed worse results for short implants used implants with a smooth surface [24,25]. Our results and success rates are in accordance to recent systematic reviews and literature tendency in regard to indication, surface treatment, prosthetic connection and success rates of short implants [38].

Studies favorable to the use of short implants smaller than 7mm a common feature was noticed in almost every system studied: abutment/implant connection type morse taper [3,11]. These connections seem to play crucial role in reducing the incidence of mechanical complications since in the treatments with short implants the crown/implant ratio is unfavorable.

In this study, there was no loosening of the abutment despite the unfavorable crown/implant ratio, greater than or equal to 1.3 (mean of 1.73). Titamax WS implants have an internal Morse cone prosthetic connection. This connection allows for the close contact between the abutment and the implant [20], generating an important mechanical overlap. The frictional retention between the conical walls is responsible for retaining the abutment on the implant, ensuring its non-rotation during clinical use, a fundamental characteristic for unitary rehabilitation. In this system, bite force acts in favor of increased locking [31]. This explains the low incidence of mechanical complications found in our study. Most studies that showed worse results for short implants used systems with an external hexagonal abutment/implant connection [24,25].

Only two mechanical complications have been reported. In two cases, the prosthesis screw was loosened. In one case, this loosening could be explained by the occlusal conditions present. The patient had an anterior open bite and, as a result, the absence of anterior and lateral disocclusion guides. In addition, when in occlusion, he presented contacts only in premolars and molars. The implant tooth was in region #2 (Implant 6) and even with great care in the occlusal adjustment, it was not possible to prevent overload. A new adjustment was made and the crown screwed again without further loosening or complications on the total period evaluated. In the second case of loosening of the crown, a great rotational freedom of the crown was perceived on the abutment. This problem was probably caused by failures in the casting process or problems in the manufacture of the castable cylinder and could have been avoided if a prefabricated metal base cylinder had been used. In this case, a new crown was made and no other prosthetic problems observed.

Albrektsson et al. [39] defined some criteria for the evaluation of success in treatments with osseointegrated implants of the Branemark System and it is still nowadays used as a parameter for success in the literature. Marginal bone loss is one of the indicators used to attest success or a tendency to failure over time [40]. In this work, bone loss in the vertical direction and bone loss in the horizontal direction were evaluated separately. The average vertical bone loss in the total 5 -year follow-up period, was 0.58 ± 0.49 mm. The greater percentage of vertical bone loss was observed in the osseointegration period, without prosthetic loading. Bone losses after loading, both horizontal and vertical, were non-significant in all the evaluated periods. Therefore, we can hypothesize that the surgical trauma during implant drilling and placement was the major cause of bone loss.

An important observation about the level of the implant surgical installation can be made. With the exception of Implants 1 (region #19) and Implant 9 (region #18), all others had vertical bone loss, ranging from 0.45mm to 1.25mm (average of 0.58mm). The implants that were installed exactly at the bone level as recommended by the system protocol started to have a smaller osseointegrated area, including the explosion of some supra-bone threads. However, the implants that were installed slightly intra-osseous are still fully submerged and therefore with a greater area of bone-implant contact. The total bone level present in the moment of implant placement did not influence the amount of marginal bone loss, but it was possible to verify that the implants placed at the bone level had a smaller area of bone/implant contact [41,42]. Only a longer clinical follow-up and a larger amount of implants placed intra-osseous would determine whether the installation at the bone level bone represents a greater risk for the failure of Titamax WS implants in this research and in a general basis. This is an important topic to be studied in the future in regard to this specific and similar implants and protocols oriented by the manufacturer.

Short implants placement at intra-bone level requires special care in relation to osteotomy. The first bone cortex plays a critical role in primary stability, and in many cases the entire body of the implant is located solely in the medullar bone. In these cases, osteotomy should be reduced and adapted according to bone density, therefore the clinical experience of the operator is essential.

As previously shown, a significant amount of bone loss was attributed to surgical trauma, although some precautions were taken. The implants were installed by the same professional with experience in the implantology field. The learning curve is believed to significantly interfere with results, especially when using short implants. All instrumentation was performed with low rotation per minute, around 250 rpm, with new cutters and plenty irrigation, all these precautions were aimed to cause the least trauma possible to bone tissues. Osteotomy was customized for each clinical situation taking into account the type of bone and the characteristics of the implant used, aiming at primary stability with an installation torque not exceeding 60 N/cm. In some cases of medullar bone, sub-instrumentation was used to generate primary stability, in other instances of highly corticalized bone, it was necessary to repeat the last cutter in order to reduce excessive loading torque.

A concern in dental rehabilitation with short implants, especially in single cases, is the ratio between the prosthetic crown and the implant length. Most of the time this proportion is higher than expected. For many years, a crown/root ratio ranging from 0.5 to 1 has been used in rehabilitation with fixed dental prostheses.

In the dental case, the root fixation mechanism is the periodontal ligament, which is highly reactive to occlusal overloads. In dental implants rehabilitation, the distribution of occlusal forces has shown its own mechanisms quite different from natural teeth, probably due to the fact that there is a bone/implant "ankylosis". In this work, the influence between crown/implant ratio and the mesio/distal width of the prosthetic crown on peri-implant bone loss was verified. There was no correlation between these parameters and vertical and horizontal bone losses. The different proportions of implant length and crown as well as mesio/distal width did not had any effect on bone loss. Other studies have also attempted to show a correlation between these parameters and marginal bone loss and found no relationship between these variables [28-30].

The follow-up time after prosthetic loading was five years, indicating a good prognosis since most implant losses occur even before prosthetic loading and peri-implant bone loss is more significant in the first year [42]. Only three implants did not present vertical bone loss during the total follow-up period as shown in Table II represented by the positive values. The greater amount of bone loss found in other implants was attributed to surgical trauma and was compatible with bone loss found in other studies in the same period, even with longer implants, different abutment/implant connections and multiple cases. In other words, the use of short implants for single rehabilitations did not represent so far, a difference in the peri-implant bone tissue behavior.

All issues discussed here, such as success index, peri-implant bone loss, mechanical and biological complications, showed that the implants studied presented favorable behavior for their use even in the studied clinical situation. However, it remains to be seen whether these results will be sufficient to maintain success rates in the long term, given that among the limitations of this study, the small sample size and bone loss data not associated with gingival profile data can be highlighted.

CONCLUSION

The short implants studied in this work used in single rehabilitation showed a success rate higher than or equal to the indexes for longer length implants found in the literature. In addition, the level of bone loss found was also within the normal range when compared to other clinical studies regardless of the length of the implants. The different proportions of implant length and crown as well as mesio/distal width did not had any effect on bone loss. It is suggested that for this type of implant, internal morse connection is favorable. The placement of the Neodent WS implants (and similar implants) in an intra-osseous protocol and not at bone level needs further investigation because it might present better results in regard to vertical bone loss over time.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author's Contributions

CDSJ: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Writing – Original Draft Preparation, Writing – Review & Editing. MGCS: Writing – Original Draft Preparation, Writing – Review & Editing. RZA: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Writing – Original Draft Preparation, Writing – Review & Editing. HHMM: Data Curation, Formal Analysis, Investigation, Methodology, Validation. FDN: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing.

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

This study protocol was reviewed and approved by Research Ethics Committee of the Faculty of Dentistry of Ribeirão Preto, University of São Paulo, approval number 2009.1.199.58.3.

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