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Influence of orthodontic force on immediately loaded implants

A influência da força ortodôntica em implante submetidos a carga imediata

La influencia de la fuerza de ortodoncia en implantes sometidos a carga inmediata

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Abstract
This study aimed to evaluate the influence of orthodontic force on dental implants subjected to immediate loading in adult's human patients. For this patients with absence of mandibular posterior teeth undergoing orthodontic treatment, whose planning requires skeletal anchorage, were selected and submitted to implant installation surgery with a Morse Cone prosthetic connection and a torque of 45 N.cm. After the molding, confection and installation of the provisional prostheses in infraocclusion, Edgewise/Ricketts lower double-tube orthodontic fittings were bonded, and the mechanics of the accompanying arches for the molar verticalization were initiated, supported by the implant force ranging from 50 to 150 g, up to 6 months. *Marginal bone loss* and Resonance Frequency Analysis (RFA) were performed at T0 - immediately after provisional installation and T1 – 180 days after implantation. The results showed a total of 9 patients were initially selected, totaling 10 implant surgeries. However, only 5 implants presented primary stability greater than 45 N.cm. *Marginal bone loss* analysis showed an average of 1.21 ± 1.66 mm of bone losses, no statistically significant differences (P = 0.690) between the mesial (1.09 ± 1.6 mm) and distal (1.34 ± 1.9 mm) regions was observed. The RFA results showed a significant difference (P=0.008) in the ISQ values presented between the T0 (67.3 ± 11.7) and T1 (76.8 ± 4.95). The conclusion showed the orthodontic force does not interfere with the stability of immediate loading implants. Further studies with larger sampling and extended evaluation times are necessary to attain more consistent results.
Keywords: Orthodontic anchorage procedures; Dental implants; Orthodontics.

Resumo
Este avaliou a influência da força ortodôntica em implantes submetidos a carga imediata. Para isso foram selecionados pacientes com ausência de dente posterior mandibular, que estão em tratamento ortodôntico cujo planejamento se faz necessário ancoragem esquelética. Os pacientes foram submetidos a cirurgia de instalação de implantes com conexão protética Cone Morse e torque de 45 N.cm. Em seguida, foi realizada a moldagem, confecção e instalação dos provisórios em infraoclusão. Em seguida, foram feitas as fixações ortodônticas de tubo duplo inferior de Edgewise / Ricketts e, em seguida, iniciada a mecânica dos arcos de acompanhamento para a verticalização dos molares, sustentados pelo implante com variação entre 50-150 g, por 6 meses. Foram realizadas análises perda óssea marginal e de frequência de ressonância (RFA) nos períodos T0 (imediatamente após a instalação do provisório) e T1 (180 dias). Foram selecionados 9 pacientes totalizando 10 implantes mandibulares. Porém apenas 5 implantes apresentaram estabilidade primária superior à 45N.cm. Na análise da perda óssea marginal, notou-se perda óssea de 1,21 ± 1,66 mm, sendo que não houve diferença estatisticamente significativa entre a região mesial (1,09 ± 1,6mm) e distal (1,34

± 1,9mm) (P = 0.690). Já na análise RFA, houve diferença estatisticamente significativa entre os períodos T0 (67,3 ± 11,7) e T1 (76,8 ± 4,95) com valor de P=0,008. A força ortodôntica não interfere na estabilidade de implantes de carga imediata. Novos estudos com maiores períodos de acompanhamento e avaliação são necessários para se obter resultados mais consistentes.
Palavras-chave: Procedimentos de ancoragem ortodôntica; Implantes dentários; Ortodontia.

Resumen
Este estudio tuvo como objetivo evaluar la influencia de la fuerza ortodóncica en implantes dentales sometidos a carga inmediata en pacientes humanos adultos. Para ello se seleccionaron pacientes con ausencia de dientes posteriores mandibulares sometidos a tratamiento de ortodoncia, cuya planificación requiere anclaje esquelético, y se les sometió a cirugía de instalación de implantes con conexión protésica de Cono Morse y torque de 45 N.cm. Después del moldeado, confección e instalación de las prótesis provisionales en infraoclusión, se adhirieron los accesorios de ortodoncia de doble tubo inferior Edgewise / Ricketts, y se inició la mecánica de los arcos acompañantes para la verticalización del molar, apoyados por la fuerza del implante entre 50 y 150 g, hasta 6 meses. La pérdida de hueso marginal y el análisis de frecuencia de resonancia (RFA) se realizaron en T0, inmediatamente después de la instalación provisional y T1, 180 días después de la implantación. Los resultados mostraron que inicialmente se seleccionaron un total de 9 pacientes, totalizando 10 cirugías de implantes. Sin embargo, solo 5 implantes presentaron estabilidad primaria superior a 45 N.cm. El análisis de pérdida ósea marginal mostró un promedio de 1,21 ± 1,66 mm de pérdida ósea, no se observaron diferencias estadísticamente significativas (P = 0,690) entre las regiones mesial (1,09 ± 1,6 mm) y distal (1,34 ± 1,9 mm). Los resultados de RFA mostraron una diferencia significativa (P = 0,008) en los valores ISQ presentados entre T0 (67,3 ± 11,7) y T1 (76,8 ± 4,95). La conclusión mostró que la fuerza ortodóncica no interfiere con la estabilidad de los implantes de carga inmediata. Se necesitan más estudios con muestreo más amplio y tiempos de evaluación más prolongados para lograr resultados más consistentes.
Palabras clave: Procedimientos de anclaje de ortodoncia; Implantes dentales; Ortodoncia.

1. Introduction

The remarkable increase in the search of orthodontic treatment associated with future prosthetic rehabilitation in adult patients has brought the need for an interdisciplinary planning into the dental clinical practice. Dental absences, bone loss, malocclusion and functional deficiencies, factors commonly found in these patients, may limit or even preclude the orthodontic treatment. The use of skeletal anchorage for orthodontic mechanics and for rigid periodontal control has greatly contributed to the success and speed of orthodontic and rehabilitation treatment in these patients (Adell & Lekholm, 1981; Willems, Carels, Naert & van Steenberghe, 1999; Huang, Shotwell & Wang, 2005; Cravero & Ibañez, 2008).

The use of dental implants as orthodontic anchorage was described decades before the discovery of Brånemark's osseointegration (Brånemark, Aspegren & Breine, 1964). Although not presenting stimulating results, Gainsforth & Higley (1945), using vitallium screws, and Linkonw (1969), using laminated implants, reported the use of orthodontic forces supported by endosseous implants.

The implementation of the concept of osseointegration allowed a safe, predictable and durable solution for oral rehabilitation, thus stimulating the development of researches aimed at analyzing the use of dental implants for orthodontic anchorage without compromising the osseointegration (Linkonw, 1969; Majzoub et al., 1999; Saito et al., 2000; Melsen & Lang, 2001; Gotfredsen, Berglundh & Lindhe, 2001a; Gotfredsen, Berglundh & Lindhe, 2001b; Gotfredsen, Berglundh & Lindhe, 2001c; Huang, Shotwell & Wang, 2005; Oyonarte, Pilliar, Deporter & Woodside, 2005; Hsieh et al.,2008; Cravero & Ibañez, 2008; Palagi et al., 2010; Ferrari et al., 2015; Podaropoulos et al., 2016; Marins et al., 2016; Rismanchian et al., 2017). Most of these studies were performed using animal models (Linkonw, 1969; Majzoub et al., 1999; Saito et al., 2000; Melsen & Lang, 2001; Gotfredsen, Berglundh & Lindhe, 2001a; Gotfredsen, Berglundh & Lindhe, 2001b; Gotfredsen, Berglundh & Lindhe, 2001c; Huang, Shotwell & Wang, 2005; Oyonarte, Pilliar, Deporter & Woodside, 2005; Hsieh et al.,2008; Ferrari et al., 2015; Podaropoulos et al., 2016; Rismanchian et al., 2017, assembling the histological analysis in addition to the clinical and radiographic analysis, while a few studies in humans (Cravero & Ibañez, 2008; Palagi et al., 2010; Marins et al., 2016) performed clinical, radiographic and Resonance Frequency Analysis (RFA) with the purpose of verifying the bone region around the implants, its stability and possible changes in the implant position.

Regarding the application of forces, studies have shown that the use of orthodontic forces, i.e. up to 300 g, did not affect osseointegration of the dental implant (Linkonw, 1969; Majzoub et al., 1999; Saito et al., 2000; Melsen & Lang, 2001; Gotfredsen, Berglundh & Lindhe, 2001a; Gotfredsen, Berglundh & Lindhe, 2001b; Gotfredsen, Berglundh & Lindhe, 2001c; Huang, Shotwell & Wang, 2005; Oyonarte, Pilliar, Deporter & Woodside, 2005; Hsieh et al.,2008; Cravero & Ibañez, 2008; Palagi et al., 2010; Ferrari et al., 2015; Podaropoulos et al., 2016; Marins et al., 2016; Rismanchian et al., 2017) and may even contribute to the increased in bone density (Saito et al., 2000; Melsen & Lang, 2001), especially if there is a progressive increase in strength (Podaropoulos et al., 2016). However, forces above 500 g (considered orthopedic) can promote the movement of the implant, while maintaining osseointegration (Hsieh et al.,2008; Rismanchian et al., 2017). When orthodontic force is used, the loading time and force direction (traction or compression) (Majzoub et al., 1999) and the size of the implant (Linkonw, 1969) did not influence in the success of the osseointegration process.

Following scientific evidence of the feasibility of using dental implants for anchoring in an attempt to reduce the total time required for orthodontic and rehabilitative treatment, in 2010, Palaglia et al. (2010) evaluated the use of orthodontically dental implants loaded immediately after implant installation surgery in human adult's patients. After 2 years of follow-up, patient's results of clinical and radiographic analysis showed no significant difference in the osseointegration quality of the dental implants loaded with immediate orthodontic force, and ensuing the osseointegration period. This finding was also histologically proven by Rismanchian et al. (2017) after analyzing the immediate loading implants technique in dogs.

Therefore, considering the need to reduce the orthodontic treatment time and the need to have better control of orthodontic mechanics, the main objective of this research was to evaluate the use of immediate implants for orthodontic anchorage in human patients through radiographic analysis and Resonant Frequency Analysis, up to the period of 6 months after surgical intervention. The researchers believe in the hypothesis that the immediate orthodontic force applied after the installation of immediate load implants will not impair the osseointegration process.

2. Methodology

Patients Selection

This prospective study was submitted and approved by the Ethics Committee for Research on Human Subjects at Araraquara University (UNIARA) under protocol number 3.156.422. A total of 9 adult patients were selected among those already undergoing dental treatment at the University of Araraquara.

The inclusion criteria for the study were: patients with dental augmentation in the posterior mandible, patients requiring orthodontic skeletal anchorage. All implants had an initial lock of 45 N.cm and were installed at the bone and infra bone level. The exclusion criteria were: presence of any systemic alteration, smokers, alcoholics, chronic users of medication that can alter bone metabolism and the presence of parafunctional habits encountered in patient's protocols.

Surgical procedures and implants installation

The surgical procedure was performed sterically in an outpatient setting initiating with local anesthesia (4% articaine with 1:100,000 epinephrine - Articaine®, DFL-Brazil), followed by the incision over the designated region using a 15c scalpel blade attached to a number 3 scalpel handle, subsequently the skin flap was detached. After the exposure of the bone tissue, the preparation of the receiving implant bed followed the protocol proposed by the manufacturer, considering the diameter of the implant to be used with the aid of an acetate surgical guide, which was made from a diagnostic waxing to ensure the installation at the location previously determined within the orthodontic planning. The drilling *procedure* was accomplished with *800 rpm* under copious saline 0.9% irrigation.

The implants (Prosthesis System Connection, Arujá, São Paulo, Brazil) were installed with a torque of 45 N.cm with a Morse Cone prosthetic connection; with lengths ranging from 10, 11.5 and 13 mm according to available bone height in the designated region, respecting a distance of 2 mm from the mandibular canal, remained with their respective cover screws. After the surgical procedure was completed, 5-0 nylon sutures were performed.

A total of 10 implants were performed in 9 patients, considering that one female patient was submitted to 2 implants. Patients were instructed regarding diet, postoperative care, oral hygiene instructions and were prescribed with postoperative medication of Amoxicillin 500 mg (1 capsule 8/8 hours – for 7 days), Nimesulide® 100 mg (1 tablet 12/12 hours for 3 days period – Aché Pharmaceutical Laboratories S.A., Guarulhos, São Paulo, Brazil) and Dipyrone® 500 mg (1 tablet 6/6 hours for 3 days period, in case of pain – Boehringer Ingelheim, São Paulo, Brazil), in addition to the use of Alcohol-free Periogard® mouthwash (5 mL mouthwash, *3 times* a day for 30 s - Colgate-Palmolive Co. LLC, São Paulo, Brazil).

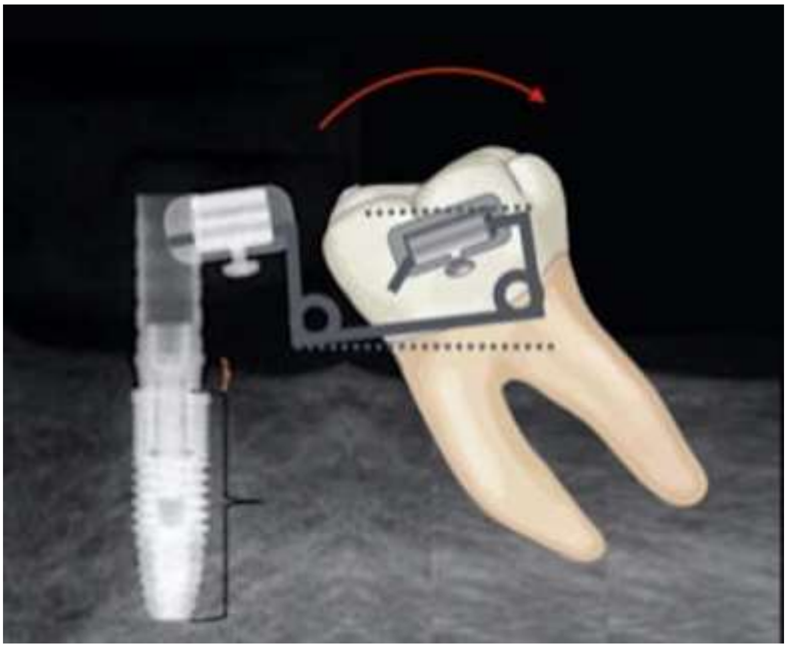
Implant-supported transitional prosthetic rehabilitation

The provisional implant-supported prostheses were screwed directly into the implant with a torque of 20 N.cm (as recommended by the manufacturer) and a periapical radiograph was performed to confirm the adaptation of the prosthesis over the implant. To prevent the accumulation of food and debris in the access holes, the screws were sealed with Teflon and Bioplic light - curing temporary restorative (Biodynamic Chemical and Pharmaceutical LLC, Ibiporã, PR, Brazil). The provisional prostheses were made in infraocclusion with reduction of the occlusal table. All patients were instructed regarding oral hygiene care and diet.

Orthodontic anchorage

After the installation of the provisional crowns, the 0.18 Edgewise/Ricketts lower double-tube orthodontic fittings were bonded (Morelli Ortodontia LLC, Sorocaba, SP, Brazil), and immediately after tube bonding, the mechanics of follow-up arches for molar verticalization were started, supported by the implant previously installed. Molar up righting was performed by cantilevers made with 16x16 blue elgiloy wire (Rocky Mountain Orthodontics® RMO® Denver, Colorado) as shown in Figure 1. A 150gr-mm force was used. A variation of 50-100mg force was employed depending on the distance of the implant to the tooth to be moved.

Figure 1: Scheme of molar up righting was performed by cantilevers made with 16x16 blue elgiloy wire.



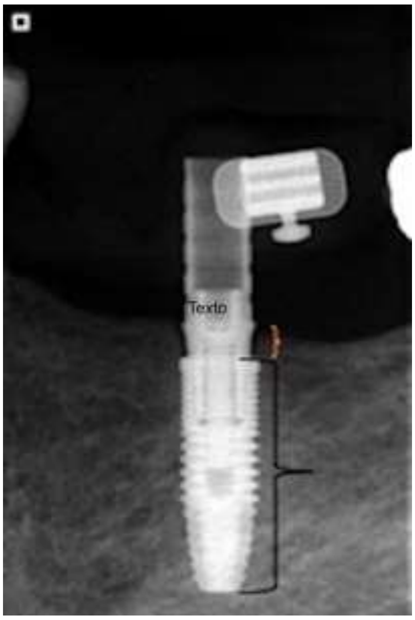
Source: Authors.

Marginal bone loss analysis

To evaluate in situ changes in the *crest bone* region, digital periapical radiographs were performed using the Digital Radiography device (Gendex®, Hatfield, USA). The positioning was standardized by a self-curing acrylic guide JET® (JET, Diógenes Ribeiro de Lima, SP, Brazil) made for each patient immediately after the installation of the orthodontic mechanics, so that the X-ray cone was always perpendicular to the digital film, which was parallel to the long axis of the implant and always in the same position in relation to the implanted crown. The guide was referred to the provisional implant crown already with the orthodontic accessory installed. Radiographic analysis were performed at Time 0 (T0 - immediately after the implant and orthodontic attachment installation) and Time 1 (T1 - 180 days after the surgical procedure).

To measure the peri-implant bone height, the images obtained were calibrated according to the implant length and the measurements were performed using the uppermost portion of the implant platform as a reference point until bone contact with the implant body. These analysis were performed using Image Analysis Software Image J® (National Institutes of Health, Bethesda, USA) and were performed after proper calibration by two different operators (Figure 2).

Figure 2: Demonstrative image of the area measured on radiographic examination.



Source: Authors.

Resonance Frequency Analysis

Resonance Frequency Analysis (RFA) were performed using the Osstell® device (Osstell®, Gothenburg, Sweden) handled by a single operator after proper calibration. The Osstell® RFA uses transducers connected to implants or prosthetic components available for various systems, while the Smart pegs gives a fixed lateral force to components so the system displacement can be measured.

The value obtained by Osstell® is automatically translated into an index called the Implant Stability Coefficient (ISC) or Implant Stability Quotient (ISQ), which ranges from 1 to 100. For the analysis of RFA of each implant, a type 21 Smart peg coupled to the micro unit was used, with torque of 4 to 6 N.cm. Measurements were performed on the mesial, distal, buccal and lingual surfaces and the mean of these values performed at the periods T0 and T1 were considered for the final RFA value of each implant.

Statistical analysis

Data were expressed as mean ± standard deviation. The Kolmogorov – Smirnov normality test was used to assess the normality of data distribution for all variables. The t-test was performed comparing T0 and T1 of each implant. A significance level of 5% ($p \leq 0.05$) was used for all analyzes. All statistical tests were performed by GraphPad Prism® 6.0 software (GraphPad Software®, La Jolla, California, USA). All data were reviewed by an independent statistician.

3. Results

A total of 9 patients were initially selected and submitted to mandibular implants, totaling 10 implant surgeries, considering that a female patient received 2 implants. However, only 5 implants presented primary stability greater than 45 N.cm, equally divided (50%) into male (2) and female (2) patients, presenting an average age of 53.4 years old.

Based on the radiographic analysis data, bone loss between T0 and T1 (T1-T0) was 1.21 ± 1.66 mm, and there was no statistically significant difference ($p = 0.690$) observed between the mesial (1.09 ± 1.6 mm) and the distal region (1.34 ± 1.9 mm) (Table 1).

Table 1: Values related to implant length (mm) and vertical bone loss (mm) at times T0 and T1 and the site of pressure in the cervical region.

Patients	Implant Length (mm)	Orthodontic Forces	T0		T1	
			Mesial	Distal	Mesial	Distal
1	11,5	Distal	1,054	1,786	-2,871	-2,898
2	10	Distal	0	-0,715	-0,454	-1,023
3	10	Mesial	0	0	-0,688	-0,819
4	10	Distal	0,738	0	0,622	0
5	10	Distal	0	0,65	-0,273	-0,279
Mean ± SD	-	-	**0,36 ± 0,5**	**0,34 ± 0,94**	**-0,73± 1,29**	**-1,00± 1,13**

* Negative values refer to measurements below the implant platform. Source: Authors.

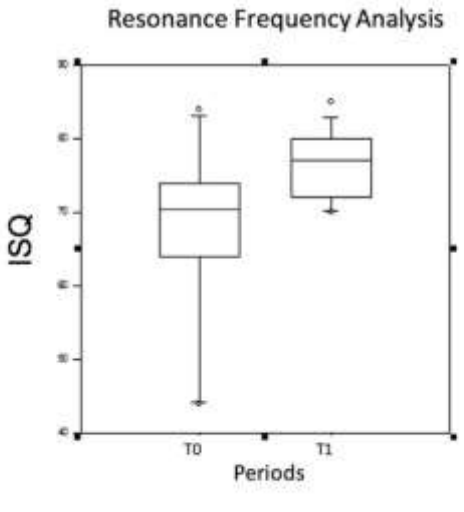
Regarding the Resonance Frequency Analysis (RFA), there was a statistically significant difference between the T0 (67.3 ± 11.7) and T1 (76.8 ± 4.95) periods ($p = 0.008$). The comparison between the T0 and T1 periods by region (mesial, buccal, lingual and distal) showed no statistically significant differences (Figure 3 and Table 2).

Table 2: Resonance frequency values at times T0 and T1.

Patients	Insertion Torque (N.cm)	Orthodontic Forces	T0				T1			
			Mesial	Distal	Buccal	Lingual	Mesial	Distal	Buccal	Lingual
1	60	Distal	64	64	57	64	72	72	70	72
2	35	Distal	74	74	74	74	80	76	77	76
3	45	Mesial	67	44	46	44	72	72	70	72
4	45	Distal	84	84	75	75	83	83	85	83
5	35	Distal	73	73	68	68	80	80	80	80
Mean ± SD	-	-	**72,4± 7,7**	**67,8 ± 15**	**64 ± 12,3**	**65 ± 12,6**	**77,4 ± 5,08**	**76,6 ± 4,88**	**76,4 ± 6,5**	**76,8 ± 4,88**

Source: Authors.

Figure 3: Resonance Frequency Analysis, showing the mean and standard deviation of T0 and T1, as well as the statistically significant difference between the periods.



Source: Authors.

4. Discussion

The main objective of the research was to evaluate the use of immediate implants for orthodontic anchorage in human patients, comparing radiographic and Resonance Frequency Analysis data collected immediately after surgery (T0) and also within 6 months after their implantation procedures (T1). Through data analysis, it was possible to confirm the hypothesis that immediate orthodontic force in the installation of immediately loaded implants does not impair the osseointegration and the implant stability.

The standardization of orthodontic mechanics for molar verticalization within the same force range (between 50-150 g) and the use of immediate implants of the same type in the mandibular posterior region with similar insertion torques and compatible immediate loading resulted in a well-cohesive sample, retaining the results. However, although the initial sample counted with 10 mandibular implants, 5 losses occurred due to the lack of adequate conditions to insert the immediate load, which resulted in a reduction of the study population to only 5 samples. The initial Resonance Frequency Analysis T0 (67.3 ± 11, 7), associated with the minimum torque of 45 N.cm contributed to define the conditions for the immediate loading. The choice to use the mandibular posterior region was made due to the higher success rate using the immediate loading protocol, given the bone quality in the region. (Nkenke & Fenner, 2001)

Although one of the first reports in the literature about the use of dental implants as anchorage is a case report (Willems, Carels, Naert & van Steenberghe, 1999), there are still a few publications of clinical studies (Cravero & Ibañez, 2008; Palagi et al., 2010; Marins et al., 2016) using the same approach, being further reduced when evaluating immediate loads protocols[16]. Clinical studies are unanimous in concluding that the use of dental implants as orthodontic anchorage does not affect the osseointegration and the stability of osseointegrated implants (Cravero & Ibañez, 2008; Marins et al., 2016) or of the immediate loading (Palagi et al., 2010), in conformation with the results obtained in this study. It is *worth mentioning* that all studies accessed in the literature used orthodontic forces between 60-200g (Cravero & Ibañez, 2008; Palagi et al., 2010; Marins et al., 2016) presenting clinical (Palagi et al., 2010; Marins et al., 2016) radiographic (Cravero & Ibañez, 2008; Palagi et al., 2010; Marins et al., 2016) and RFA (Marins et al., 2016) data analysis (Table 03).

Table 3: Research related to orthodontic force applied in dental implants.

Author, Year	Implants (n)	Orthodontic Forces	Analyzes	Follow up (months)	Conclusion
Cravero et al.[2] 2008	93 implants - convencional loaded	F=100g F=200g	Resonance frequency	2 to 9 (mean: 3.5)	The implants were able to withstand orthodontic forces without significant bone change.
Palagia et al.[16] 2010	9 implants- immediately loaded; 11 implants convencional loaded	F= 60 a 200g	Two instrument mobility	24	The application of immediate orthodontic force doesn’t alter the success of osseointegration.
Marins et al.[19] 2016	50 implants - convencional loaded	F= 200cN	Radiographic and clinical	3, 6 and 9	Osseointegrated implants are considered a safe technique as orthodontic anchorage.

Source: Authors.

Histologically, the use of dental implants as orthodontic anchorage contributes to increase bone density and bone-implant contact (BIC) without affecting implant placement or stability (Saito et al., 2000; Melsen & Lang, 2001; Gotfredsen, Berglundh & Lindhe, 2001a; Podaropoulos et al., 2016; Rismanchian et al., 2017). However, if forces above 600 g (considered orthopedic) are used, an implant movement can be observed, without affecting its osseointegration (Hsieh et al., 2008; Rismanchian et al., 2017).

Frost's mechanostatic theory (Frost, 1983; Frost, 1987; Frost, 1992) highlights the law of use and disuse. It could be the explanation for the improvement of bone density and BIC, emphasizing that there is a “minimum effective rate” where the stimulus would generate bone gain and if this stimulus is insufficient (disuse) or excessive, bone resorption could occur.

When evaluating horizontal bone loss, the average obtained in this study was 1.21 ± 1.66 mm, a value compatible with the predicted saucerization described by Consolaro et al. (2010). These results are also similar to those found by Marins et al. (2016) when resorption of mesial and distal bone ridges was observed (p = 0.1832) during the evaluation period.

The orthodontic mechanics used in all cases of this study was for posterior teeth verticalization. In this mechanics, one side of the implant suffers greater pressure in the cervical region than the other, although there was no significant difference in the results obtained between the sides in both RFA and vertical bone loss values. These results are similar to the study presented by Saito et al. (2000) who observed no differences between the pressure side and the stress exerted on implants.

5. Conclusion

This prospective study demonstrated that the use of light but constant orthodontic forces in immediately loaded implants does not compromise its stability. These results are in agreement with those presented in the literature; however, it is noteworthy that even if a cohesive sample was obtained, further studies with larger sampling and extended evaluation times are necessary to attain more consistent results.

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