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Evaluation of Effect of Different Insertion Speeds and Torques on Implant Placement Status and Removal Torque in Polyurethane Dense D1 Bone Model

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Abstract: The aim of this study was to evaluate the effect of two different insertion speeds at 8 different insertion torque values ranging from 25-60 during implantation in a dense polyurethane D1 bone model on the placement status and removal torque of dental implants. In this study, 50 pcf single layer polyurethane plates were used. In the study, a total of 320 implant sockets were divided into 2 groups as Group 1 (30 rpm) and Group 2 (50 rpm) in terms of insertion speed. Group 1 and Group 2 were divided into 8 subgroups as 25, 30, 35, 40, 45, 50, 55 and 60 torques. There were 20 implant sockets in each subgroup. During the implantations, implant placement status and removal torque values were assessed. There was a statistically significant difference between the 30 and 50 RPM groups in terms of overall implant placement status ($p<0.01$). It was found that the removal torque values at 50 RPM were statistically significantly higher than those at 30 RPM ($p<0.01$). This study showed that in dense D1 bone, the minimum parameters at which all implants could be placed at bone level were 50 torque at 30 rpm and 40 torque at 50 rpm.

Keywords: polyurethane modal; polyurethane foam; polyurethane plate; dental implant; insertion torque; removal torque; implant placement status

1. Introduction

Dental implants have been widely used over the past 30 years because of their ability to replace missing teeth and restore the ultimate aim of today's dentistry, namely to re-establish the patient's function, speech, health and aesthetics, regardless of stoma-tognathic atrophy, disease or injury [1]. It provides an advanced therapy that closely resembles the look, feel and function of natural teeth, including speech and chewing. Unlike removable dentures, implant-supported dentures do not move during function. This helps to maintain the contour and attractiveness of the face by reducing bone loss and changes to nearby healthy teeth [2]. Craniofacial reconstructions, skeletal anchors and orthodontic appliances are also stabilised by dental implants [3]. Therefore, dental implants are currently a very prominent alternative and have allowed significant de-velopment in dental, oral and maxillofacial surgery due to their high success rate, pre-dictability and reliability of treatment and relatively minimal complications [4,5]. Re-search indicates that while numerous design aspects play a significant role, an individual's bone quality is a major component in predicting the effectiveness of dental implants. In terms of patient characteristics and health status, the majority of dental implants in healthy individuals have a success rate of between 90 and 95% after ten years. [6–8].

Several factors have been identified as critical to implant success and stability [9]. There are two types of implant stability It is a biomechanical phenomenon involving the bone quality and quantity at the implant region necessary for implant osseointegration. Secondary stability follows the healing period and corresponds to primary stability, improving as new bone develops and matures at the interface [10,11]. Patient's medical condition, the quality of the bone, the surgical technique, the composition of the biomaterial, the width, length, and geometry of the implant, biomechanical considerations, and surface characteristics are all important considerations during dental implant planning in order to improve osseointegration and, ultimately, the long-term success of the implant. [11–13]. When assessing implant stability, bone density is an important factor to consider. Failure rates are generally attributed to inadequate bone quantity and/or quality resulting in inadequate fixation [14–16]. According to studies, dental implants positioned in the lower jaw are more likely to survive than those positioned in the upper jaw, particularly in the posterior upper jaw [17,18]. Clinicians generally believe that bone quality is the main reason for the difference in survival rates between the upper and lower jaw [19]. Implants inserted in Type IV bone may have a higher failure risk, according to numerous research in the literature. Researchers have also documented positive results from implants inserted into Type I, II, and III bone. [20].

Various materials have been used in the literature for in vitro bone modelling. Human and animal cadavers and polymers are commonly used [21–23]. Human cadavers and animal models have similar properties to natural tissues but have disadvantages such as biosafety, safe transport and storage costs. Polyurethane is a family of polymers with diverse properties and applications that are all based on the exothermic reaction of organic polyisocyanates with polyols.It is used in many different medical fields, including vascular and orthopaedic, due to its unique mechanical properties and biocompatibility [24–26]. The American Society for Testing and Materials has accepted polyurethane sheets as an alternative material for biomechanical testing and evaluation of dental implants. Polyurethane sheets do not mimic human bone structure, but have mechanical properties similar to bone tissue. Their mechanical properties allow standardisation of procedures by eliminating existing anatomical and structural differences in bone [27,28]. Polyurethane foam sheets have been identified as the most suitable material for in vitro use, simulating bone tissue and different densities to compare the stability of dental implants and bone screws [29]. However, polyurethane is reliable, easy to use and does not require any special treatment [30,31].

The bone density at the implant site affects the optimal loading time, implant design, and treatment strategy [32,33]. There is a linear correlation between primary stability levels and bone density, as demonstrated by numerous research [20,34–36]. These studies have used different techniques to assess bone density and primary stability. Insertion torque (IT) measurements are a widely used technique for the objective assessment of primary stability [37]. The ideal insertion torque has been the subject of numerous studies that have been published in the literature. [19,38–41]. Although there seems to be no consensus in these studies, torque values between 25-70 are recommended as implant insertion torque. In addition, some implant manufacturers have established maximum torque values to prevent structural damage and complications that may occur in the implant, implant carrier and insertion spacers due to excessive torque during implantation [42].

There are many studies in the literature evaluating different surgical protocols for dif-ferent bone densities. These studies have evaluated the effect of different protocols used during socket preparation, which is the first step of dental implant surgery, on implant insertion torque [27,43,44]. However, no research on the impact of torque and insertion speed on implantation during the second stage of implantation was discovered. Although the companies' socket preparation protocol is followed during implant surgery, extremely high torque values are achieved during implantation, especially in dense D1 bone, which prevents the implant from settling in the socket [45]. It can be seen that there is no optimal implantation protocol that allows the implant to be placed at bone level in dense D1 bone. Establishing a protocol for dense D1 bone by determining the minimum insertion speed and torque values for implantation will minimise the complications that may occur with the bone and implant. The aim of this study was to evaluate the effect of two different insertion speeds at 8 different insertion torque values ranging from 25-60 during implantation in a dense polyurethane D1 bone model on the placement status and removal torque of dental implants.

2. Materials and Methods

This single-blind in vitro study was conducted at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Van Yüzüncü Yıl University in March 2024. Two 25x15x2.5 cm polyurethane plates with a density of 50 per cubic foot (pcf) were prepared for the study to be used as a dense D1 bone model in vitro. The literature suggests that the density of polyurethane corresponding to D1 bone is 30-40 pcf and cortical bone is 50 pcf [46,47], so in this study we chose to use single layer 50 pcf polyurethane plates to create a dense D1 bone model. The plates were coded by the assistants with the numbers 1 and 2 and the letters a, b, c, d, e, f, g and h to blind the author surgeon who would perform the implantation, and only the assistants knew which letter and number belonged to which group. The preparation of the implant sockets in the plates was performed according to a protocol established by an independent surgeon outside the study. Implantation in the groups was performed by the same author surgeon. A 3.75x10mm dental implants (MarsTM , Medigma Biomedical GmbH, Wehingen, Germany) was used in the study. The implant placement status and the insertion and removal torques of the implants in the groups were measured and recorded. Based on the results of a previous study, the sample size was determined with an alpha error of 0.05, an effect size of 0.45 and a power (1-beta) of 0.80. A minimum sample size of 10 implant sockets was calculated for each subgroup [48].

Study Groups

In the study, a total of 320 implant sockets were divided into 2 groups as 30 revolutions per minute (RPM)(group 1) and 50 RPM (group 2) in terms of insertion speed. Group 1 and Group 2 were divided into 8 subgroups as 25, 30, 35, 40, 45, 50, 55 and 60 torques. There were 20 implant sockets in each subgroup (Figure 1).

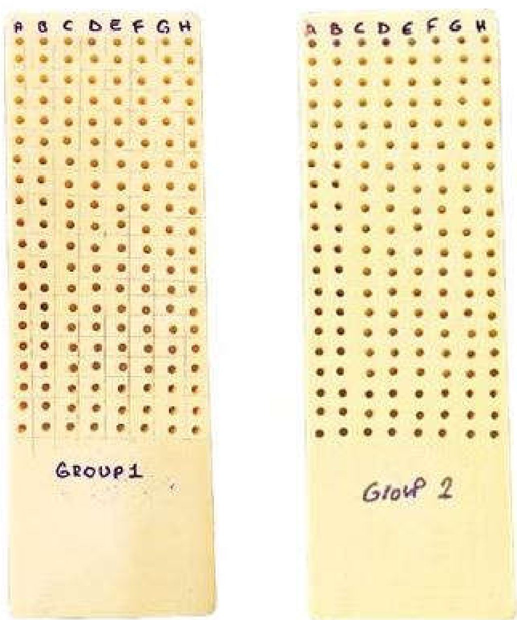

Figure 1. Preparation of implant sockets for groups 1 and 2 (A=25 torque group; B=30 torque group; C=35 torque group; D=40 torque group; E=45 torque group; F=50 torque group; G=55 torque group; F=60 torque group)**.**

Implant Socket Preparation Protocol

The standard drilling protocol for 3.75x10 mm implants from the implant company was used to prepare the implant sockets in 8 subgroups in polyurethane plates. Drilling was performed under saline irrigation using a physiodespenser at 1000 RPM with a torque setting of 70 and an implant handpiece with a 1:20 reduction. In group 1, implantation procedures were performed with the physiodespenser device in 8 subgroups of 25, 30, 35, 40, 45, 45, 50, 55 and 60 torque groups with the torque value of the respective group and a standard speed of 30 RPM. In group 2, the implantation procedures were performed with the physiodespenser device in 8 subgroups of 25, 30, 35, 40, 45, 50, 55 and 60 torque groups with the torque value of the respective group and a standard speed of 50 RPM. During the implantations, implant placement status and removal torque values were assessed. Implant placement status was evaluated as placement or non-placement of the implant at bone level in the socket.For the removal torque value, the insertion torque value of the corresponding group was taken as the reference, and the first value at which the implant rotated in the socket was taken as the removal torque, starting from the reference torque value and increasing by 5 torques in each trial.The removal torque evaluation was performed at the same RPM at which the implant was placed (implant removal was performed at 30 RPM for the 30 RPM group and 50 RPM for the 50 RPM group).The physiodespenser and implant handpiece could measure up to a maximum torque value of 80. For implants that could not be removed with a torque value of 80, a manual torque ratchet was used that could measure up to 100 torques. Implants with a removal torque value greater than 100 were considered to have a removal torque value of 100. In both groups, the distances between the implant sockets of the 8 subgroups were kept similar and there were no complications in the implant sockets.

Statistical Analyses

SPSS 26.0.0 (Statistical Package for the Social Sciences) was used for statistical analyses in the evaluation of the results obtained in the study. In evaluating the study data, quantitative variables were presented using mean, standard deviation, median, minimum and maximum values, and qualitative variables were presented using descriptive statistical methods such as frequency and percentage. The Shapiro-Wilks test and box plots were used to assess the suitability of the data for normal distribution. Student's t-test was used for quantitative evaluations of two groups showing normal distribution, paired sample t-test for within-group evaluations, one-way ANOVA test for comparisons of three groups and above, and Bonferroni test to determine the group causing the difference. Chi-square test was used to compare qualitative data. Results were evaluated with 95% confidence interval and significance at $p<0.05$ level.

3. Results

A total of 320 implant sockets were included in the study. When the placement of the included implants in the sockets was analysed, it was found that 56.9% (n=182) were placed in the socket at bone level and 43.1% (n=138) were not placed in the socket. Implant removal torques ranged from 40 to 100, with a mean of 80.81±19.22 (Table 1).

Table 1. Distribution of Descriptive Characteristics.

		n (%)
Implant placement status	Bone level	182 (56,9)
	Not fully inserted	138 (43,1)
Implant removal torque	Mean±Sd	80,81±19,22
	(Min-Max)	(40-100)
Group	30 Rpm	160 (50,0)
	50 Rpm	160 (50,0)

Torque subgroup	25 torque	40 (12,5)
	30 torque	40 (12,5)
	35 torque	40 (12,5)
	40 torque	40 (12,5)
	45 torque	40 (12,5)
	50 torque	40 (12,5)
	55 torque	40 (12,5)
	60 torque	40 (12,5)

There was a statistically significant difference between the 30 and 50 RPM groups in terms of overall implant placement status (regardless of torque level) (p=0.001; p<0.01). When comparing the 8 subtorque groups, it was found that the rate of implant placement status of the bone level was higher at 50 RPM than at 30 RPM at 35, 40 and 45 torque levels (p=0.001; p<0.01). There was no difference in implant placement status between 30 and 50 RPM at other torque levels (p>0.05). When comparing the total implant removal torque values (regardless of torque level), it was found that the removal torque values at 50 RPM were statistically significantly higher than those at 30 RPM (p=0.001; p<0.01) (Table 2).

Table 2. Comparison of Implant Placement Status and Implant Removal Torque Values according to RPM Groups.

		30 Rpm (n=160)	50 Rpm (n=160)	[a]p
Total	Bone level	66 (41,3)	116 (72,5)	[a]0,001**
	Not fully inserted	94 (58,8)	44 (27,5)	
25 torque	Bone level	-	-	-
	Not fully inserted	20 (100)	20 (100)	
30 torque	Bone level	-	-	-
	Not fully inserted	20 (100)	20 (100)	
35 torque	Bone level	0 (0)	16 (80,0)	[a]0,001**
	Not fully inserted	20 (100)	4 (20,0)	
40 torque	Bone level	2 (10)	20 (100)	[a]0,001**
	Not fully inserted	18 (90)	0 (0)	
45 torque	Bone level	4 (20)	20 (100)	[a]0,001**
	Not fully inserted	16 (80)	0 (0)	
50 torque	Bone level	20 (100)	20 (100)	-
	Not fully inserted	-	-	
55 torque	Bone level	20 (100)	20 (100)	-
	Not fully inserted	-	-	
60 torque	Bone level	20 (100)	20 (100)	-
	Not fully inserted	-	-	
Implant removal torque	Mean±Sd (Min-Max)	75,31±21,49 (40-100)	86,31±14,75 (50-100)	[b]0,001**

[a]Pearson Chi-Square Test [b]Student-t Test **p<0,01.

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Intra-Group Implant Removal Torque Assessments

When the torque groups were evaluated in general and within the 30 and 50 RPM groups, a statistically significant difference was found between the implant removal torques (p=0.001; p<0.01). Pairwise comparisons were made to determine the source of the difference; while the removal torques of the implants in the 25 torque group were not significantly different from those in the 30 torque group (p>0.05), they were lower than those in the 35, 40, 45, 50, 55 and 60 torque groups (p<0.05). While the removal torques of the implants in the 30 torque group were not significantly different from those in the 35 torque group (p>0.05), they were lower than those in the 40, 45, 50, 55 and 60 torque groups (p<0.05). While the removal torques of the implants in the 35 torque group were not significantly different from those in the 40 torque group (p>0.05), they were lower than those in the 45, 50, 55, 60 torque groups. The removal torques of the implants in the 40 torque group were lower than those in the 45, 50, 55, 60 torque groups. The removal torques of the implants in the 45 torque group were not significantly different from those in the 50, 55, 60 torque group (p>0.05). The removal torques of the implants in the 50 torque group were not significantly different from those in the 55, 60 groups; the removal torques of the implants in the 55 torque group were not significantly different from those in the 60 torque group (p>0.05).Assessments within the 30 RPM group (Table 3).

Table 3. Intragroup Comparison of Implant Removal Torque Values in RPM Groups.

	Torque subgroup	Mean±Sd	(Min-Max)	[c]p
Total (n=320)	25 torque	56,00±9,14	(40-70)	[c]0,001**
	30 torque	61,50±11,67	(40-80)	
	35 torque	70,50±12,50	(45-100)	
	40 torque	76,00±17,44	(45-100)	
	45 torque	92,00±10,55	(75-100)	
	50 torque	95,00±8,77	(80-100)	
	55 torque	96,00±8,10	(80-100)	
	60 torque	99,50±3,16	(80-100)	
30 Rpm (n=160)	25 torque	49,25±6,13	(40-60)	[c]0,001**
	30 torque	52,50±10,07	(40-80)	
	35 torque	61,00±10,08	(45-80)	
	40 torque	65,25±15,85	(45-100)	
	45 torque	92,50±10,58	(75-100)	
	50 torque	90,00±10,26	(80-100)	
	55 torque	93,00±9,79	(80-100)	
	60 torque	99,00±4,47	(80-100)	
50 Rpm (n=160)	25 torque	62,75±6,17	(50-70)	[c]0,001**
	30 torque	70,50±2,76	(65-75)	
	35 torque	80,00±5,38	(70-100)	
	40 torque	86,75±11,39	(70-100)	
	45 torque	91,50±10,77	(75-100)	
	50 torque	100,00±0,00	(100-100)	
	55 torque	99,00±4,47	(80-100)	
	60 torque	100,00±0,00	(100-100)	

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Post-hoc		25 torque	30 torque	35 torque	40 torque	45 torque	50 torque	55 torque	60 torque
Total	25 torque								
	30 torque	1,000							
	35 torque	0,001**	1,000						
	40 torque	0,001**	0,007*	0,678					
	45 torque	0,001**	0,001**	0,001**	0,004**				
	50 torque	0,001**	0,001**	0,001**	0,001**	1,000			
	55 torque	0,001**	0,001**	0,001**	0,001**	1,000	1,000		
	60 torque	0,001**	0,001**	0,001**	0,001**	1,000	1,000	1,000	
30 Rpm	25 torque								
	30 torque	1,000							
	35 torque	1,000	1,000						
	40 torque	0,372	1,000	1,000					
	45 torque	0,001**	0,001**	0,001**	0,004**				
	50 torque	0,001**	0,001**	0,001**	0,012*	1,000			
	55 torque	0,001**	0,001**	0,001**	0,002**	1,000	1,000		
	60 torque	0,001**	0,001**	0,001**	0,001**	1,000	1,000	1,000	
50 Rpm	25 torque								
	30 torque	1,000							
	35 torque	0,006**	0,347						
	40 torque	0,001**	0,003**	1,000					

45 torque	0,001**	0,001**	0,490	1,000			
50 torque	0,001**	0,001**	0,001**	0,138	1,000		
55 torque	0,001**	0,001**	0,002**	0,256	1,000	1,000	
60 torque	0,001**	0,001**	0,001**	0,138	1,000	1,000	1,000

[c]One-Way ANOVA Test Post-hoc (Bonferroni test) **p<0,01.

Inter-Group Implant Removal Torque Assessments

When the implant removal torque values were compared between the groups, it was found that the implant removal torques at 50 RPM in the 25, 30, 35, 40, 50 and 55 torque groups were statistically significantly higher than those in the 30 RPM group (p=0.001, p=0,017; p<0.01, p<0.05). In the 45 and 60 torque groups, no statistically significant difference was found between the implant removal torques at 30 and 50 RPM (p>0.05) (Table 4).

Table 4. Inter-group Comparison of Implant Removal Torque Values in RPM Group.

Torque subgroup	30 Rpm (n=160) Mean±Sd (Min-Max)	50 Rpm (n=160) Mean±Sd (Min-Max)	[b]p
25 torque	49,25±6,13 (40-60)	62,75±6,17 (50-70)	0,001**
30 torque	52,50±10,07 (40-80)	70,50±2,76 (65-75)	0,001**
35 torque	61,00±10,08 (45-80)	80,00±5,38 (70-100)	0,001**
40 torque	65,25±15,85 (45-100)	86,75±11,39 (70-100)	0,001**
45 torque	92,50±10,58 (75-100)	91,5±10,77 (75-100)	0,769
50 torque	90,00±10,26 (80-100)	100,00±0,00 (100-100)	0,001**
55 torque	93,00±9,79 (80-100)	99,00±4,47 (80-100)	0,017**
60 torque	99,00±4,47 (80-100)	100,00±0,00 (100-100)	0,329

[b]Student-t Test **p<0,01 *p<0,05.

4. Discussion

In recent years, polyurethane has been reported to have similar biomechanical properties to human bone and also to have a more homogeneous average cell size than natural bone [30,31,49]. Polyurethane bone models are a standard and homogeneous material that can be produced in various thicknesses and densities from D1 to D4 [28,30]. Therefore, polyurethane bone models are suitable for biomechanical testing of dental implants such as insertion torque (IT), removal torque (RT) and

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resonance frequency analysis (RFA) evaluation [27,28,47,50,51]. According to the Misch classification, a polyurethane block with a density of 0.48-0.64 g/cc (30-40 PCF) resembles D1 bone in vivo and simulates cortical bone [52]. As reported in the literature, polyurethane block was preferred for modelling D1 bone in this study due to its many advantages. To evaluate and model implant placement in dense D1 bone, a 50 pcf polyurethane plate was used. There were no complications with the preparation of the implant sockets. Again, despite the high insertion and removal torques during implant placement and removal, no complications were observed with either the plates or the implant sockets. The study used a physiodispenser and implant handpiece with a torque value of 80, which is the highest torque value of the devices currently used on the market and mimics the clinical environment [53]. In general, it can be seen that the removal torques of implants with an insertion torque of 45 and above are higher than 80. It is obvious that this situation, which we believe is due to both the dense D1 bone and the design of the implant, in cases where it is necessary to remove the implants in the clinical environment, it is obvious that the implant tools and handpieces used to remove the implant will wear out under these high torques, or the worn parts will not be able to remove the implant and cause unwanted complications [54,55]. When we evaluated the insertion speed, 80 and higher removal torque values were obtained at insertion torque values of 35 and above in the 50 RPM group, and 80 and higher removal torque values were obtained at insertion torque values of 45 and above in the 30 RPM group. Correspondingly, higher implant removal torques were achieved in the 50 RPM group for implants with the same insertion torque.

Implant stability is one of the most important factors for successful implant treatment and numerous studies have shown that primary implant stability is important for implant success and longevity [10,56] . Implant stability is essential for bone cell differentiation and osseointegration [57]. Satisfactory stability during the healing period prevents excessive micromovement and disruption of bone formation [58]. Bone density, implant characteristics and surgical technique are the factors that influence primary implant stability [37,59]. The main characteristics of the implant are the implant material and the micro and macro design of the implant [60,61]. Grooves have been incorporated into implants to optimise the initial contact of the implant with the socket, increase stability [56,62], increase the surface area of the implant and positively distribute stress [63–65]. McCullough and Klokkevold [66] reported that aggressive groove design provides higher insertion torque and primary stability. Today, most implant manufacturers produce tapered implants. The reason for the preference for tapered implants is that tapered implants increase primary implant stability by creating lateral compression in the bone in areas of weak bone and in cases with anatomical limitations [67,68]. Rokn et al [69] recommended the use of tapered implants to achieve better primary stability in areas with inadequate bone quality and quantity due to the greater lateral compression force that tapered implants exert on the surrounding bone. Similarly, Lozano-Carrascal et al [70] reported that tapered implants had higher ISQ values and insertion torque values than cylindrical implants. In this study we preferred a tapered implant in accordance with the literature. When comparing different bone types, the bone type with the highest primary implant stability is D1 bone. As bone density increases, so does primary stability [71,72]. There is no study in the literature that investigates the minimum torque value at which the implant can be placed in different bone types. It can be seen that the focus of the studies is to determine the minimum torque suitable for immediate or early loading [39,73]. However, there is no data on the minimum torque at which the implant can be placed in the socket at bone level without being outside the socket in different bone types. High primary implant stability is desirable, but increasing torque is known to increase bone and implant-related complications [74]. In the search for the optimal implant insertion torque that both allows early loading protocols and does not cause bone and implant-related complications, the optimal torque value should also meet the minimum torque value that allows the implant to be inserted at bone level in different bone types. In this sense, this study was the first to evaluate the minimum implant insertion torque at which the implant can be placed at bone level in dense D1 bone type. In the 50 rpm group, the minimum torque level at which all implants were placed at bone level was 40, whereas in the 30 rpm group, this value was set at 50 torque. In addition, while 80% of the implants in the 50 rpm group were placed at a torque value of 35, none of the implants in the 30 rpm group

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could be placed at bone level. The fact that the removal torque values were 80 and above for the torque values at which the implants were placed at bone level in both groups is further evidence that these minimum values provide sufficient primary stability.

In their study, which is the only study in the literature to evaluate implant insertion speed during implantation, Hsu et al. [75] found that implant stability, i.e. implant insertion torque, decreased with increasing implant insertion speed in both good and poor bone types. In contrast to the study by Hsu et al, this study found that the rate of implant placement in the socket at bone level and the implant removal torque increased with increasing insertion speed during implant placement. We believe that the reason we found a different result from the study by Hsu et al. [75] is that the torque values were kept constant when evaluating the effect of insertion speed in this study. Our results show that increasing the insertion speed at torque levels where the implant cannot be embedded in the socket, especially within certain limits, allows the implant to be placed at bone level. The dense D1 bone type is particularly common in the anterior mandible and in the atrophic mandible [76,77]. When working in these cases, it is important to remember that the bone present may be very dense D1 bone, and in this case we recommend using the placement torque and speed values presented in this study. In the study we found that the removal torque values were higher than the insertion torque values in all torque groups and speeds. We believe that this is due to the fact that the structural changes in the socket walls are minimal even at high insertion torques, particularly due to the density of the polyurethane sheets used. These results suggest that a 50 pcf polyurethane sheet can be used to model dense D1 bone. The implant used in the study was a tapered implant with self-tapping threads. If an implant with different characteristics had been used, the results may have been different. Although a standardised protocol was used to prepare the implant sockets, there may have been minimal surgeon-induced variation in the width of the sockets. Although we took care to ensure that the distance between the sockets was the same when creating the implant sockets, any minimal variations or differences that may have occurred could have affected the results by affecting the thickness of the socket walls.

5. Conclusions

In conclusion, this study was the first in the literature to evaluate the effect of implant insertion speed on implant placement at the bone level at different implant insertion torques in dense D1 bone type. In the 50 rpm group, the rate of implant placement at the bone level was found to be higher than in the 30 rpm group. In dense D1 bone type, the minimum parameters in which all implants could be placed at the bone level were determined to be 50 torque when working at 30 rpm and 40 torque when working at 50 rpm. These results obtained for the dense D1 bone type should be confirmed in further in vitro and clinical studies. We also recommend further studies evaluating the effects of the factors investigated in this study in implants with different designs and different bone types.

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