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In Vitro Evaluation of the Primary Stability of Implants Placed at Different Angles in D2 and D4 Bovine Bones

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Key words: Implant, primary stability, angulation, bone classification, resonance frequency analysis, computed tomography

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Abstract: The aim of this study was to evaluate the primary stability of implants placed in D4 and D2 type bovine bones at different angles *in vitro* by using Resonance Frequency Analysis (RFA) and measuring Insertion Torque Value (ITV) and Reverse Torque Value (RTV) of implants. A total of 89 implants were placed in bone blocks harvested from bovine femur and tibia. The angualtion for placing implants were 0, 10, 20 and 30°. The bone densities of recipient sites were determined by density value as Houns eld Units (Hu) using cross-sectional CT scans based on Lekholm and Zarb classification and tactile sense of the surgeon based on Misch's classification. Primary stability was measured by Osstell (ISQ), ITV by OsseoCare and RTV by TQ-8800 Torque Meter (N cm^{-1}). One-way ANOVA was used to compare the ISQ, ITV and RTV at different angles and Spearman's rho was employed to evaluate the relationship between Hu, angulation, bone density, tactile sense of the surgeon, ISQ, ITV and RTV. There was a statistically signi cant difference of ISQ value in D4 but not in D2 ($p>0.05$). No significant difference of ITV and RTV was found in D2 and D4 at defined angles. Moreover, Spearman's rho test results showed a significant and direct relationship between ITV and ISQ; between ITV and RTV and between RTV and angulation in D2 and D4 type bones ($p<0.05$). In D4 type bone, angulation can increase the primary stability of the implant, so, to avoid resurgery, implants should be placed with an angle of 10° to improve its stability.

INTRODUCTION

Nowadays, important factors that affect success of implant treatment are primary stability, bone biology, implant design and osseointegration. Osseointegration is "a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant"[1]. Primary stability is used as an essential criterion for the success of osseointegration[2]. Although, primary stability clinically has not defined clearly but generally the lack of movement immediately after implant placement is considered as primary implant stability[3]. Primary stability mostly comes from the mechanical engagement between implant and bone[2]. Lack of primary stability will result in fibrous tissue around the implant[4]. Studies have identified different factors affecting primary implant stability. For Atsumi *et al*.[5] these factors are: bone quality and quantity, surgical techniques including the skill of the surgeon and implant factor including length, geometry, diameter and surface characteristics. Turkyilmaz *et al*.[6] divided these effective factors into two groups: patient-related (bone volume and quality) and procedure-dependent parameters including type of implant and type of surgical procedure. Other proposed factors are: stress and mismatch strain between implants and surrounding bone[7].

Several techniques have been reported in various studies to evaluate bone density as the most important factor in bone quality and stability. Lekholm and Zarb[8] were the first scientists claimed that bone density evaluation is an important factor in predicting the results of implant therapy. They classified bone quality as type I, II, III and IV. Misch[9] in evaluating the bone quality and stated that there are significant differences between the different bone qualities with respect to the tactile sense of the surgeon during osteotomy. Accordingly, he classified four types of bone density as D1, D2, D3 and D4 based on macroscopic structure of bone from the highest density to the lowest density. Given the importance and effect of bone quality on primary stability of implants, we can conduct a risk assessment in different situations by examining the primary implant stability at different angles and in D2 (the most common bone density) and D4 (the weakest type of bone density), reduce the risk of implant failure in the long term and hence have a successful implant therapy. Many studies have been conducted on assessing implant stability in different bone densities using different techniques. In Meredith[10]'s study the used techniques for assessing implant stability and osseointegration were the clinical measurement of cutting resistance during implant placement and reverse torque following osseointegration. They found that stability both at placement and during function is an important criterion for the success of dental implants. Vidyasagar *et al*.[11] tested implant stability in relation to five implant designs (thread geometry and crest module) in pig ribs using Resonance Frequency Analysis (RFA). Different implant designs achieved a similar primary stability, so, they concluded that design features for improving primary stability are less important in dense bone. Molly[12] stated that many methods of primary implant stability assessment are available including insertion torque value, periotest, Osstell and RFA. They showed that primary stability measurements have significant correlations with different bone densities and also with implant outcome. Turkyilmaz *et al*.[13] studied the relations between the bone density and implant stability parameters. Implant stability measurements were performed with the Osstell machine. Statistically significant correlations were found between bone density and insertion torque values ($p<0.001$); bone density and Implant Stability Quotient (ISQ) values ($p<0.001$) and insertion torque and ISQ values ($p<0.001$). They suggested that the bone density values from pre-operative Computed Tomography (CT) examination may provide an objective assessment of bone quality and significant correlations between bone density and implant stability parameters may help clinicians to predict primary stability before implant insertion. In another similar study conducted by Pages *et al*.[14] studied relation between bone density in Hounsfield units and primary implant stability by insertion torque and RFA. A statistically significant relationship was observed between bone quality density and location with ISQ values. Also, there was a correlation between bone quality, according to the Lekholm and Zarb[8] classification and Hu computerized tomography values. They suggested that, according to the correlation of Hu and RFA, Hu can be used as a diagnostic parameter to predict possible implant stability. Moreover, the primary implant stability measured with RFA depends on bone density values, bone quality and implant location. Considering previous research, the purpose of this study is to evaluate the primary stability of implants placed at different angles of 0, 10, 20 and 30° in D2 and D4 type bone densities by using RFA (ISQ) method and calculating Insertion Torque Value (ITV) and Reverse Torque Value (RTV) of implants.

MATERIALS AND METHODS

In this *in vitro* experimental study, we used bone blocks prepared from bovine femur and tibia bones. The used implants (DIO UF 3811S, DIO Corporation, Korea) had 11 mm length and 3.5 mm diameter. Bone blocks put into two groups of D2 and D4 based on their CT scan results according to the Misch's bone density classification. A casting mold was made from these bone blocks by silicone. After preparing the plaster model for each of the blocks (Fig. 1), surgical stents were made on each plaster model using cold a wax Visible Light Cure (VLC). After preparation of surgical stents, different angles of 0, 10, 20, 30° were marked on each stent randomly (Fig. 2). Then, using milling machine, the defined angles were drilled into the surgical stents (Fig. 3). Afterwards, root canal filling material (gutta percha) was placed into each of the holes related to 0, 10, 20 and 30° angles and then were scanned by Cone-Beam Computed Tomography (CBCT) device. The scans were re-examined by Romexis software and the correct locations that at the same time had the density and the desired angle were selected. The bone samples and stents then were presented to the surgeon. The surgeon was totally blind to the bone type and its classification.

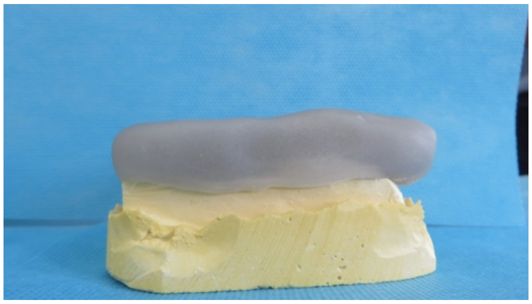

Fig. 1: A sample of plaster cast used in the study

Fig. 2: Surgical stents for embedding angled holes

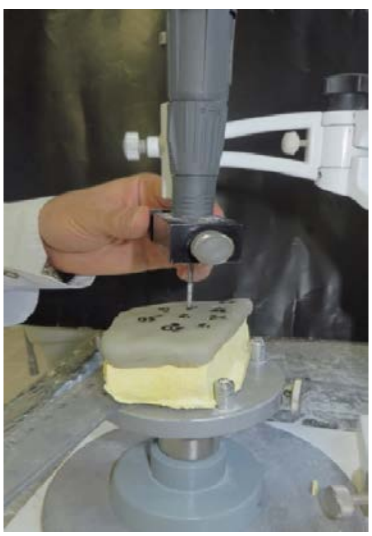

Fig. 3: Drilling stents in defined angles by a milling machine

The implant osteotomy was performed using surgical micromotor system (NSK Surgic XT plus) at 800 rpm. A total of 89 implants were placed in the bone blocks (45 in D2 and 44 in D4 group) by OsseoCare machine. Then, the ITV was determined by this device and recorded in N cm^{-1} unit. ITV represents the resistance of bone during implant placement with the increase in ITV, the primary stability of the implant should be increased. After this

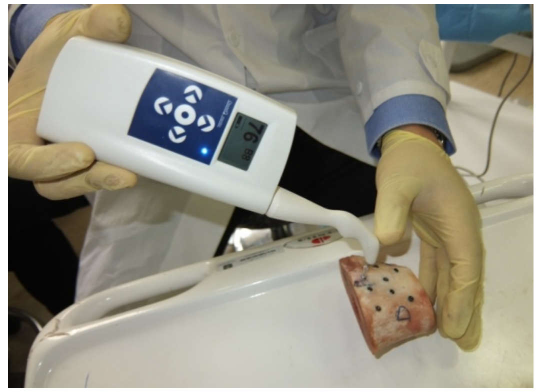

Fig. 4: ISQ measurement by Osstell Mentor

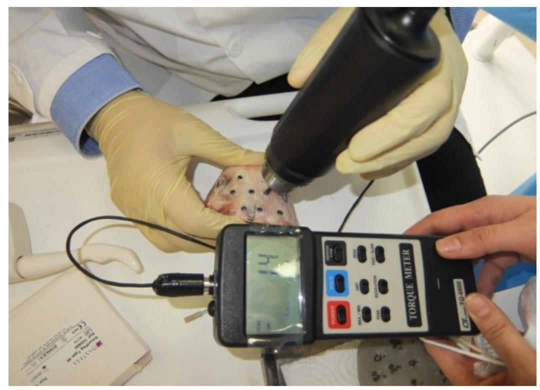

Fig. 5: RTV measurement by TQ-8800 Torque Meter

step, resonance frequency measurements (ISQ) were recorded by Osstell device (Osstell AB, Gothenburg, Sweden) (Fig. 4). Measurements were done at the occlusal, buccal, mesial, distal and lingual sides and their mean value was used in statistical analysis. Finally, RTV was measured in N cm^{-1} unit using Torque Meter device model TQ-8800 (Fig. 5) and was recorded for each specimen. With reverse torque test, we can measure critical torque threshold at the bone-implant interface.

The data analysis was performed in SPSS v. 19 software using statistical tests. Mean and standard deviation were used for presenting the statistics of surgeon's sense, Hu, ISQ, ITV and RTV. For comparing two D2 and D4 groups in term of these factors, one-way ANOVA test and for comparing them with respect to different angles of placed implants, Tukey's test were used. Also, for examining the correlation between bone density, surgeon's sense, Hu, ITV, RTV and ISQ, Spearman's rho was employed. Statistical level was set at 0.05.

RESULTS AND DISCUSSION

Bone density evaluation by surgeon's tactile sense based on Misch's classification: Results of ssurgeon's

Table 1: Accuracy of ssurgeon's tactile sense in bone density evaluation during drilling

Sense of surgeon/Bone type	D1	D2	D3	D4	Total
D2	6 (13.3%)	39 (86.66%)	-	-	45
D4	-	-	18 (40.9%)	26 (59.1%)	44

Table 2: CT scan results accuracy of bone density evaluation

Lekholm and Zarb[8] index/Bone type	I	II	III	IV	Total
D2	1 (2.22%)	40 (88.8%)	4(8.88%)	-	45
D4	-	-	6 (13.63%)	38 (86.36%)	44

Table 3: Primary stability of implants placed on D2 bone type at different angles

			Confidence interval of 95%	
ISQ/Angle	Mean	SD	Min.	Max.
0	79.3091	3.58705	73.00	84.40
10	76.2000	5.55959	60.40	81.60
20	77.4182	5.79272	64.60	82.80
30	77.2756	5.48441	63.00	82.80

Table 4: Primary stability of implants placed on D4 bone type at different angles

			Confidence interval of 95%	
ISQ/Angle	Mean	SD	Min.	Max.
0	56.6909	7.45137	43.60	63.80
10	65.5636	3.27270	62.00	73.60
20	62.0727	4.42020	54.060	67.20
30	61.4909	6.08629	48.60	71.40

tactile sense in determining the bone density during drilling and osteotomy to place implant in bovine bone blocks are presented in Table 1. Of 45 osteotomy samples in bone type D2, the surgeon classified 39 samples correctly (86.66%). In 6 samples (13.3%) the surgeon diagnosed D1 bone type. Also, of 44 osteotomy samples in bone type D4, the surgeon classified 26 samples correctly (59.1%) and in 18 samples (40.9%), his assessment was type D3.

Bone density evaluation (Hu) by CT scans based on Lekholm and Zarb classification: Results showed in group D2, of 45, forty samples (88.8%) were diagnosed accurately by cross-sectional CBCT scans as type II, while one sample (2.22%) was diagnosed as type I and four samples (8.88%) as type III. Moreover, using CT scans in group D4, 38 samples (86.36%) were diagnosed accurately as type IV and 6 samples (13.63%) as type III (Table 2).

ISQ: The mean±standard deviation of the primary stability resonance frequency (ISQ) values in D2 group at zero degree was reported as 79.3091±3.58705; at 10° as 76.2000±5.55959; at 20° as 77.4182±5.79272 and at 30° was 77.2756±5.48441 (Table 3). One-way ANOVA results showed that ISQ value in D2 bone type is not significantly different when the implants placed at different angles (Sig. = 0.517>0.05).

Also, mean±SD of ISQ value in group D4 at 0° was obtained as 56.6909±7.45137; at 10° as 65.5636±3.27270; at 20° as 62.0727±4.42020 and at 30° it was 61.4909±6.08629 (Table 4). Moreover, according to one-way ANOVA results, there was a significant difference of ISQ value at different angles (Sig. = 0.006<0.05). Also, according to Homogeneity of variance test and Tukey's test, a significant difference was observed between ISQ index of 0 and 10° angled implants (Sig. = 0.003<0.05) but no significant difference was found between other angled implants.

Table 5: ITV of bone type D2 during different angled implants placement

			Confidence interval of 95%	
ITV/Angle	Mean (N cm^{-1})	SD	Min.	Max.
0	46.5455	7.68588	30	50
10	43.6667	9.35495	30	50
20	46.5455	7.68588	30	50
30	48.2727	5.72872	30	50

ITV: Mean±SD of insertion torque value in bone type D2 during 0° implant placement was reported as 46.5455±7.68588; at 10° as 43.6667±9.35495; at 20° as 46.5455±7.68588 and at 30° it was 48.2727±5.72872 N cm^{-1} (Table 5). Moreover, according to one-way ANOVA results, no significant difference of ITV was found in D2 type bone during the placement of implants at different angles (Sig. = 0.557>0.05).

Mean±SD of insertion torque value in bone type D4 during the placement of 0° implants was 8.2727±2.4109; at 10° was 11.6364±3.52910; at 20° was 10±0 and at 30° it was 11.8182±6.80908 N cm^{-1} (Table 6). Also, one-way ANOVA results showed no significant difference of ITV in D4 type bone during the placement of implants at different angles (Sig. = 0.151>0.05).

RTV: Mean±SD of reverse torque value in bone type D2 during 0° angulated implant removal was obtained as 53.4549±18.05195; at 10° as 48.9167±13837; at 20° as 62.4545±16.36071 and at 30° it was 68.000±18.33030 N cm^{-1} (Table 7). Also, one-way ANOVA result showed no significant difference in RTV of D2 type bone during the removal of implants with different angles (Sig. = 0.49>0.05).

Mean±SD of RTV for bone type D4 during 0° angulated implant removal was calculated as 5.1818±0.75076; at 10° as 7.4545±1.80907; at 20° as 6.7273±1.42063 and at 30° it was 9.7273±5.46076 N cm^{-1} (Table 8). Moreover, there was no significant difference in RTV of D4 type bone during the removal of implants with different angles (Sig. = 0.12>0.05).

Spearman's rho test results: Spearman's rho test results for bone type D2 is shown in Table 9. Results reported a significant and direct relationship between ITV and ISQ (Sig. = 0.004, R = 0.419); between ITV and RTV (Sig. = 0.000, R = 0.692) and between RTV and angulation (Sig. = 0.028, R = 0.328). Also, there was a significantly indirect relationship between surgeon's sense and Hu (Sig. = 0.037, R = -0.312).

According to obtained results from Spearman's rho test for bone type D4, we found a significant and direct relationship between RTV and angulation (Sig. = 0.001, R = 0.487); between ITV and ISQ (Sig. = 0.000, R = 0.718); between RTV and ISQ (Sig. = 0.000, R = 0.620) and between RTV and ITV (Sig. = 0.000, CC = 0.698) (Table 10). Also, there was an indirect and significant relationship between sense of surgeon and ISQ (Sig. = 0.001, R = -0.745); between sense of surgeon and ITV (Sig. = 0.001, R = -0.489) and between sense of surgeon and RTV (Sig. = 0.000, R = -0.599).

Various studies have discussed about the effects of bone quality and quantity on the success rate of dental implants placement. If these parameters be much more favorable, primary implant stability is improved and thereby enhances osseointegration. Thus, careful assessment of recipient sites before treatment helps the successful implant therapy. Although, there is no clear definition for bone quality but most of them considered no difference between the concept of bone density and bone quality[15]. In this study, bone quality evaluation for implant osteotomy was done by two methods: Using CT cross-sectional images based on Lekholm and Zarb[8] index and using tactile sense of the surgeon based on Misch's classification. Using Ct scans, in total, of 89 locations considered by the observer for implant placement, 78 bones (87.64%) were diagnosed correctly

Table 6: ITV of bone type D4 during different angled implants placement

			Confidence interval of 95%	
ITV/Angle	Mean (N cm^{-1})	SD	Min.	Max.
0	8.2727	2.4109	5	10
10	11.6364	3.52910	8	20
20	10.0000	0.0000	10	10
30	11.8182	6.80908	5	30

Table 7: RTV of bone type D2 during removal of different angled implants

			Confidence interval of 95%	
RTV/Angle	Mean (N cm^{-1})	SD	Min.	Max.
0	53.3545	18.05195	23	74
10	48.9167	16.13837	30	88
20	62.4545	16.36071	37	85
30	68.000	18.33030	40	89

Table 8: RTV of bone type D4 during removal of different angled implants

			Confidence interval of 95%	
RTV/Angle	Mean (N cm^{-1})	SD	Min.	Max.
0	5.1818	0.75076	4.00	7.00
10	7.4545	1.80907	5.00	10.00
20	6.7273	1.42063	5.00	10.00
30	9.7273	5.64076	5.00	24.00

Table 9: Spearman's rho analysis of bone type D2

Spearman's rho	Angulation	Hu	Sense of surgeon	ISQ	ITV	RTV	Bone quality
Angulation							
R	1.000	-0.248	0.351*	-0.074	0.119	0.328*	0.210
Sig (2-tailed)	-	0.101	0.018	0.627	0.435	0.028	0.166
N	45	45	45	45	45	45	45
Hu							
R	0.248	1.000	*0.312	0.251	0.135	0.006	**0.648
Sig. (2-tailed)	0.101	-	0.037	0.096	0.377	0.969	0.000
N	45	45	45	45	45	45	45
Sense of surgeon							
R	*0.351	*-0.312	1.000	-0.219	0.196	0.167	**0.460
Sig. (2-tailed)	0.018	0.037	-	0.148	0.197	0.272	0.001
N	45	45	45	45	45	45	45
ISQ							
R	-0.074	0.251	-0.219	1.000	**0.419	0.012	**-0.409
Sig. (2-tailed)	0.627	0.096	0.148	-	0.004	0.938	0.005
N	45	45	45	45	45	45	45
ITV							
R	0.119	0.135	-0.196	**0.419	1.000	**0.692	*-0.376
Sig. (2-tailed)	0.435	0.377	0.197	0.004	-	0.000	0.011
N	45	45	45	45	45	45	45
RTV							
R	*0.328	0.006	0.167	0.012	**0.692	1.000	0.055
Sig. (2-tailed)	0.028	0.969	0.272	0.938	0.000	-	0.722
N	45	45	45	45	45	45	45
Bone quality							
R	0.210	**0.648	**0.460	**0.409	*0.376	0.055	1.000
Sig. (2-tailed)	0.166	0.000	0.001	0.005	0.011	0.722	-
N	45	45	45	45	45	45	45

*Significant at the 0.05 level; **Significant at the 0.01 level

Table 10: Spearman's rho analysis of bone type D4

Spearman's rho	Angulation	Hu	Sense of surgeon	ISQ	ITV	RTV	Bone quality
Angulation							
R	1.000	0.072	-0.226	0.162	0.239	0.487**	0.178
Sig. (2-tailed)	-	0.642	0.141	0.294	0.119	0.001	0.248
N	45	45	45	45	45	45	45
Hu							
R	0.072	1.000	0.338*	0.558**	0.346*	0.265	0.073
Sig. (2-tailed)	0.642	-	0.025	0.000	0.021	0.082	0.638
N	44	44	44	44	44	44	44
Sense of surgeon							
R	-0.226	-0.338*	1.000	-0.475**	-0.489**	-0.599**	0.194
Sig. (2-tailed)	0.141	0.025	-	0.001	0.001	0.000	0.206
N	44	44	44	44	44	44	44
ISQ							
R	0.162	0.558**	-0.475**	1.000	0.718**	0.620**	0.068
Sig. (2-tailed)	0.294	0.000	0.001	-	0.000	0.000	0.662
N	44	44	44	44	44	44	44
ITV							
R	0.239	0.346*	-0.489**	0.718**	1.000	0.698**	-0.019
Sig. (2-tailed)	0.119	0.021	0.001	0.000	-	0.000	0.900
N	44	44	44	44	44	44	44
RTV							
R	0.487**	0.265	-0.599**	0.620**	0.698**	1.000	-0.107
Sig. (2-tailed)	0.001	0.082	0.000	0.000	0.000	-	0.491
N	44	44	44	44	44	44	44
Bone quality							
R	-0.178	0.073	0.194	0.068	-0.019	-0.107	1.000
Sig. (2-tailed)	0.248	0.638	0.206	0.662	0.900	0.491	-
N	44	44	44	44	44	44	44

*Significant at the 0.05 level; **Significant at the 0.01 level

and 11 ones (12.46%) incorrectly. Lindh *et al*.[16] used periapical radiographies to determine bone density based on Lekholm and Zarb[8] parameter. Their results showed an accuracy of 78% to diagnose bone quality with high density and 28% to diagnose low bone density. In our study, the accuracy of bone density in D4 type bone density was 86.36% and in D2 type it was 88.88%. Although, both studies showed higher accuracy for higher bone density but our accuracy results was higher which may be because we used cross-sectional CBCT scan that can has higher precision compared to periapical radiography which help the clinician for better observation of trabecular bones in CT radiography.

Using tactile sense of the surgeon for determination of bone density, of 89 bones osteotomized by the surgeon, 65 samples (73%) were diagnosed correctly and 24 ones (24%) incorrectly. Rokn *et al*.[17] found that error rate in diagnosis of bone density by tactile sense of the surgeon in D3 and D4 was higher compared to D1 and D2. This is consistent with our results. In another study, Lee *et al*.[18] showed that on average, a difference in bone density of 180 HU was required to identify differences between drilling resistance groups. But in our study, all samples that were identified incorrectly by the surgeon had a bone density difference <180 HU. So, due to the weaker sense of the surgeon in determining lower bone density, we recommend that D3 and D4 bone should be classified in one group under the title of "poor density" so that, the same conservative measures to be considered for increasing the success of implant placement for both types.

In the current study, stability of implants placed at 4 angles of 0, 10, 20 and 30° in D2 and D4 type bones was measured using RFA and measurement of ITV and RTV. Using RFA method, no significant difference was observed between different angles of placed implants in bone type D2 in terms of ISQ index (10>20>30>0). Although, in bone type D4, comparison of ISQ values showed significant difference between angles 0 and 10 degrees; no significant difference was observed between other angles. Results of Kashi *et al*.[7] was similar to our results in bone type IV, however, mean ISQ value in both bone types of D2 and D4 were higher compared to their results and studied implants in this study were more stable than those used by Kashi *et al*.[7]. This difference can be due to differences in samples as well as implants designs. We used fresh blocks of bovine femurs and DIO UF 3811S implants with 15° taper while they used polyurethane composite bone blocks and implants with a progressive thread design. Kashi *et al*.[7] suggested that high ISQ value in angled implants compared to 0° angulation can be because of configuration of the instrument during drilling which can lead to better density in middle and apical sites and the increase in cancellous bone quality and hence improve ISQ value. Also, the ISQ value in D2 at four angles was >70. Most of studies have showed that ISQ values of successful implants typically were >65 and usually implants that have ISQ value <50 may have an increased risk, especially in the case of immediate loading[19-23]. We found out that in D2 type bone, angulation does not have a significant effect on the primary stability or ISQ index and in case of immediate loading of implants, this treatment plan can be safely used but in D4 type bone, since, ISQ value was between 56 and 65 which is not in the range of specified limit for immediate loading. It is therefore, strongly recommended that immediate loading should not be conducted in this type of bone density as much as possible and it is better that implants to be placed at an angle, especially an angle of 10° to improve the primary stability.

In our study, ITV of D2 bone was 30-50 N/cm and in D4 bone, the value was 5-30 N cm^{-1}. Degidi *et al*.[24] stated that implants with a ITV less than 25 N cm^{-1} have a maximum ISQ of 50 and are placed in low ITV group, ITV in a range of 25-60 N cm^{-1} have ISQ value of 51-70 and are in moderate ITV group and those with ITV >50 N cm^{-1} have ISQ value of >71 and are placed in high ITV group. Trisi *et al*.[25] proposed that ITV in high density bones is 20-100 N cm^{-1} and in bones with lower density, it is up to 35 N cm^{-1} and it is not possible to achieve ITV higher than that. Other studies suggest an ITV of 25-45 N cm^{-1} to prevent adverse micromotion (threshold level 50-100 μ)[26] and 20-32 N cm^{-1} to achieve osseointegration[27]. Obtained results of these studies are largely consistent with our findings, therefore, it seems that according to the results, there is no problem for immediate loading of implants in D2 bone at mentioned angles but, according to ITV values of D4 bone at different angles and the emphasis of different studies on the importance of ITV as the most important index in primary stability of implants and prediction of immediate loading[28], it seems that to place implant in this type of bones regardless of placement angle, ITV can't provide desired value for immediate loading. So, it is better not do that in this type of bone which can endanger osseointegration results and long-term success of the implant. According to obtained results that indicated ITV at 10, 20 and 30° angles is higher than that at 0°, it is suggested to place implants at an angle form in this bone type to increase their ISQ value and treatment results become more predictable.

This study showed that RTV for D2 bone as 23-89 N cm^{-1} and in D4 bone it was obtained as 4-24 N cm^{-1}. As can be seen, RTV in D4 bone is lower than that in D2. This may because of lower implant-bone contact are in low density bones. Also, the force that is applied during insertion of implants can cause viscoelastic changes in the bone which can reduce implant-bone engagement and RTV compared to ITV. Obtained results showed that bone quality has direct effect on primary stability of implants. This is consistent with findings of Marquezan *et al*.[15]. They also showed that there is positive association between implant primary stability and bone mineral density of the receptor site, so that, increase in bone density can result in the increase of ISQ value.

CONCLUSION

This study showed that in bones with high quality, implant angulation has no significant effect on the increase of its primary stability and all angles provide good stability indices for different treatment protocols. Hence, doing all treatment protocols of implant prosthesis (early, delayed and late) in angled implants not only will not change but also allows clinicians to feel more confident in the use of immediate loading protocols if needed. As there was significant association between ITV and ISQ in D2 bone and at all angles ISQ>66 and ITV>32 N cm^{-1}, immediate loading protocol can be used. In the anterior maxilla that D2 and D3 bone prevalence is higher and the patients usually ask for immediate loading, implants can be placed according to the angle of natural teeth with confidence and without fear of loss of primary stability. Given that in D4 bone, implant angulation can increase the primary stability of the implant and stability in this type of bone is one of key points for its success, it is proposed that in cases where we do not want to use a two-stage implant placement protocol to avoid resurgery, implants should be placed with an angle of 10 degree to improve its stability. Also, although, there was a direct and significant relationship between ITV and primary stability in this study but this relationship was not seen in all samples, it is recommended that to check the stability, in addition to the ISQ value, the ITV index also be used and the final decision be made after considering both indices.

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