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EFFECTS OF APICAL DRILLING PRESSURE ON THE DEPTH OF DENTAL IMPLANT INSERTION WITHIN A SIMULATED OSTEOTOMY: AN *IN VITRO* STUDY

by

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A thesis submitted to the Faculty of the
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ABSTRACT

Effects Of Apical Drilling Pressure On The Depth Of Dental Implant Insertion Within A Simulated Osteotomy: An In Vitro Study

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Introduction: Rotational torque value is a commonly used measurement to determine primary stability of a dental implant. The ultimate torque value represents the friction within a prepared osteotomy of the implant and the surrounding bone. External factors, such as operator pressure during implant placement, could provide additional sources of friction resulting in differing placement depths within an osteotomy.

Objective: The aim of this study was to determine if increased apical pressure during implant placement within a simulated osteotomy results in differing implant platform depths due to increased friction within the osteotomy.

Methods: A total of 90 dental implants (Biomet 3i) were placed within custom printed polymer blocks with standardized osteotomies. A placement jig was used to place implants at three preset torque values of 20Ncm, 35Ncm and 50Ncm, using three weight levels applied to the jig to simulate apical pressure (10 implants per torque/weight combination). The weight selected to be applied to the jig was determined using a scale measuring light (680g), moderate (2080g), and heavy (3454g) digital pressure. The

distance from the implant platform to the polymer platform (IP-PP) was measured with digital calipers and recorded.

Results: At a torque setting of 20Ncm, the mean IP-PP with low, moderate, and heavy pressure was 2.351mm, 2.302mm, and 2.445mm, respectively. At a torque setting of 35Ncm, the mean IP-PP was 1.057mm, 1.089mm, and 1.051mm. At 50Ncm, the IP-PP was 0.585mm, 0.655mm, and 0.720mm. None of these values were statistically significant.

Conclusions: The effect of increasing apical pressure does not cause a statistically significant difference in depth of implant placement within a simulated osteotomy.

TABLE OF CONTENTS

LIST OF

TABLES…….**Error!**

Bookmark not defined.

LIST OF

FIGURES……..**Error!**

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LIST OF ABBREVIATONS……..ix

CHAPTER 1: Introduction……...……...1

CHAPTER 2: Materials and Methods……..5

CHAPTER 3: Results…… 8

CHAPTER 4: Discussion……9

CHAPTER 5: Conclusions……...…….11

APPENDIX A…….....20

REFERENCES……..21

LIST OF TABLES

Table 1. Characteristics of Dependent Variables by Surgical Motor Torque setting 18

Table 2. Characteristics of Dependent Variables by Apical Pressure..... 19

LIST OF FIGURES

Figure 1. Study design overview 11

Figure 2. Implant Jig Assembly 13

Figure 3. Protocol sequence 13

Figure 4. Hand Torque Wrench measurement 15

Figure 5. Osstell™ reader and Smart Peg™ 16

Figure 6. Average Insertion Torque Value of implant motor torque setting 17

LIST OF ABBREVIATONS

IP	Implant platform
PP	Polymer platform
ISQ	Implant stability quotient
RFA	Radiofrequency analysis
Ncm	Newton centimeters

CHAPTER 1: Introduction

Dental implants are a widely accepted and reliable treatment for the replacement of missing teeth. Surgical implant placement methodologies have evolved over the years. Two common treatment sequences are immediate and delayed placement. The immediate protocol entails placement of a dental implant into a socket immediately following tooth extraction, whereas the delayed protocol is where a dental implant is placed in a healed edentulous site. After placement, the implant can be submerged (two-stage) or remain exposed (single stage) during the healing process. The two-stage protocol replaces the soft tissue over the implant allowing it heal. This step is followed by a second surgical procedure 3-6 months later where the implant is uncovered and a healing abutment or dental restoration is secured to the implant. The single stage involves connecting a healing abutment or provisional crown to the implant at the time of placement.[1-3, 8] Whether the implant is placed two stage, single stage, immediate or delayed, the timing of restoration of the implant is important. If the implant is restored the same day that it is placed in bone it is referred to as immediate loading. Ultimately the choice to immediately load an implant is dependent on many factors, primarily the final insertion torque value of the implant. Nevertheless, studies have shown that all combinations of these protocols can be successful and have high survival rates if followed correctly.[2, 3, 5]

Primary stability is one of the most important factors that influences short term integration and long-term survival in delayed and immediate implants. [4, 6] Primary stability is defined as the absence of visible movement of the implant after it has been placed in bone and represents the mechanical retention of the implant. [6, 8] The most

common way primary stability is measured is by insertion torque. Dental implant insertion torque is defined as the moment of force necessary to drive an implant into a prepared osteotomy. [9] A range of torque values has been shown to be acceptable for primary stability for conventional staged approach; however, torque value becomes more important when considering immediate placement and loading of a dental implant. Studies have shown a range of 32-45Ncm as a reliable initial torque value for primary stability in immediate loading protocols. [10, 12] However, minimum torque value to obtain primary stability has not been determined. It has been shown that implants can be placed as low as 10Ncm or even as high as100Ncm, and both can be successful. [9] Another method of measuring stability of an implant is through the use of resonance frequency analysis (RFA). RFA is the measurement of the frequency with which a device vibrates and this value is translated into an index called implant stability quotient (ISQ). The Osstell™ device is used to determine the RFA of implants. The main sensor sends out a magnetic pulse causing a metal post mounted to the dental implant to vibrate. These vibrations are detected by the sensor and are translated to the ISQ index. The index range is from 1-100, with 100 being the highest. The higher the ISQ value, the more stable the implant. [13]

Many different factors can affect primary stability and torque values of implants. These include bone volume, bone density, implant geometry, and surgical technique to create the osteotomy. [13, 14] High torque values are directly correlated to primary stability of the implant. However, some studies suggest that if the torque is too high (≥70Ncm), this may cause bone micro-fracturing, decreased blood flow, increase crestal remodeling and early implant loss. [2] This concept of negative effects from high torque is somewhat

controversial. A systematic review and meta-analysis by Lemon et al. showed that high torque values do not affect implant survival or marginal bone loss. [15] This does not mean that excessively high torque is not a concern when placing implants and clinicians should not exceed manufactures recommended torque values to avoid potential implant fracture. During the placement procedure, the surgeon sets the desired insertion torque value on the implant surgical motor. The motor will stop rotating once this torque value is reached. If the implant is not fully inserted to its final planned position, the operator can adjust the torque setting on the motor or use a hand driver until the implant is inserted to the desired depth.

One factor that is not extensively studied in the literature that may affect final torque value is the apical pressure placed on the implant by the operator during placement. Standard protocols advocate "light" apical pressure during placement even though the implant should advance apically on its own due to the self-tapping thread design. However, some providers still use high apical pressure when placing their implants. A dental implant is able to advance into bone when the torque forces of the implant motor are greater than the frictional forces that are applied back on the implant by the bone. When the frictional forces equal the insertion torque of the implant motor, the motor stops rotating and the implant no longer advances. This is referred to as stalling or stall torque. For the implant to begin advancing again, the torque of the implant motor must be greater than the frictional forces of the bone on the implant. This is referred to as starting torque. It is possible that too much apical pressure on the implant would result in increased frictional forces from the bone on the implant threads causing the preset torque value on the implant motor to be achieved prematurely, resulting in the motor stalling.

This scenario would therefore create a discrepancy between the preset torque and the actual final torque value of the implant. This final torque value as previously mentioned is important for determining stability of the implant. An inaccurate value may ultimately be detrimental to the survival of the dental implant, especially if it falsely indicates immediate loading can be done. The aim of this study was to determine if increased apical pressure during implant placement within a simulated osteotomy results in differing implant platform depths due to increased friction within an osteotomy. The null hypothesis is that increased apical pressure during implant placement within a simulated osteotomy shows no statistically significant difference amongst implant platform depths.

CHAPTER 2: Materials and Methods

To test this hypothesis a bench top study was designed. An example of the study design can best be illustrated in the diagram shown in figure 1. Three main groups were created and represented by a specific torque value. Group A was 20Ncm, Group B was 35Ncm and Group C was 50Ncm. Each group had three assigned weight to represent light (680g), moderate (1400g) and heavy apical pressure (2774g). 10 implants and 10 cylinders were used for each weight in each group for a total of 90 implants placed.

In order to test this study design an implant jig was created. The device is made up of a manual drill press which serves as the main framework, a mounted implant hand piece, a digital torque reader, and 3D printed polymer cylinders with a built in osteotomy. The drill press consists of a metal base with two metal posts. A central brace connects the two metal posts and holds custom printed mounting brackets and plates for the attachment and stabilization of an implant hand piece, a digital torque reader (Model BTGE) and varying weights (Figure 2). For figure 3A, the implant motor was set at 20Ncm torque and no additional weight was added to the handpiece. Once in this position the surgical implant motor was activated and the movement of the implant into the polymer cylinder osteotomy was observed. Once the preset torque value of 20Ncm was reached, the implant stopped rotating. Figure 3D illustrates the polymer cylinder (with the implant inserted) removed from the torque reader and the distance from the implant platform (IP) to the polymer platform (PP) was measured with a digital caliper (mm) and recorded. The best way to accurately measure the implant platform to polymer platform distance was to measure the distance from the implant platform to the base of the cylinder and subtracting it from the size of the cylinder (all measuring 24.30mm). Each cylinder

was then labeled based on the group or implant motor torque value and the sequence number. These steps were repeated 9 more times with a new implant and new cylinder each time. This same process was repeated for moderate apical pressure, and heavy apical pressure illustrated in figures 3E and 3F, respectfully. This was followed by the same simulated process using three weights applied to the jig to simulate apical pressure.

The three weight amounts selected to simulate apical pressure were determined using a bench scale and digital pressure. The author pressed on the scale with his pointer finger to determine weight values that could represent light, moderate and heavy apical pressure. The light weight was based on the combined weight of the implant motor, implant bracket and the center drill press bracket and heavy pressure was determined by a blanching finger. The three weights were determined to be 680g (weight of the implant hand piece, mounting brackets, and central bracket of the implant jig), moderate weight of 2080g (weight of implant hand piece/brackets and 1400g denture flask), and heavy 3454g (addition of denture flask to the previous weights). The actual weights used in this study were metal denture flasks. These were chosen as their weight closely represented the predetermined digital pressure.

After each IP-PP measurement was completed the implant and polymer cylinder were returned to the torque reader and hand spring torque wrench was used to measure the final torque value of the implant and compare it to the preset torque value on the surgical motor. This number was then recorded.

An Osstell™ Smart peg was threaded into the implant followed by positioning the Osstell™ electronic analyzer within 3mm from the Smart peg and the ISQ value was recorded. This process was repeated 9 additional times (total n=10) at the 20Ncm torque

and same weight value (no additional weight) using a new cylinder and new implant each time. For subsequent groups, with the same torque value 1400 grams (Group B) was placed on top of the press to simulate moderate and apical pressure applied during surgery. A new implant was placed into the starting position and the operator pressed the pedal driving the implant into the polymer. This was repeated 9 additional times (n=10) with new polymer cylinders and new implants each time. All measurements previously described were recorded. This was repeated a final time at 20 Ncm torque with additional weight applied to simulate heavy apical pressure (2774 grams) (Group 3). This process was repeated for additional groups under the same simulated apical pressure conditions (no additional apical pressure, moderate apical pressure, and heavy apical pressure) with increasing torque values of 35Ncm (Group B) and 50 Ncm (Group C) set on the surgical motor (see APPENDIX A for summary of data points).

CHAPTER 3: Results

The results shown in Table 1 demonstrated that as the implant motor torque setting increased the depth of the implant into the cylinder increased. The mean distances of the implant platform to polymer platform (IP-PP) measurement were found for all three groups: Group A (20Ncm) at light pressure, moderate pressure and heavy pressure were 2.3mm, 2.3mm and 2.4mm, respectfully; Group B (35Ncm) showed a mean distance 1.05mm, 1.08mm and 1.05mm, respectfully; Group C showed a mean distance 0.58mm, 0.65mm, and 0.72mm, respectfully. A small trend was noted in Group C when apical pressure was increased, IP-PP distance was increased. Although this trend suggests decreased depth of insertion with higher apical pressure, it was not considered statistically significant. The null hypothesis was not rejected. The ANOVA (formula: IP to PP (mm)) apical pressure's main effect is statistically not significant and small ($F(2, 85)) = 2.45$, $p = 0.092$; Eta2 (partial) = 0.05, 95% CI [0.00, 1.00].

A manual torque wrench comparison to the implant motor torque setting was performed and it was shown to be similar to one another in each group and for each implant tested. The Osstell (ISQ) measurements were completed for all groups but results were inconclusive due to widely variable ISQ values and were not utilized in the final result analysis.

CHAPTER 4: Discussion

The aim of this study was to determine if increased apical pressure during implant placement within a simulated osteotomy results in differing implant platform depths due to increased friction within the osteotomy. As torque value increased the depth of the implant into the osteotomy increased. There was a significant increase in depth of around 1.5mm on average as the torque value was changed from 20Ncm to 35Ncm; however, when the torque setting changed from 35Ncm to 50Ncm the implant depth increased by less than or equal to half the distance of the first two groups. This demonstrated that as torque value increased the difference in depth between those values decreased. When apical pressure was increased in both the 20Ncm and 35 Ncm, no change in IP-PP distance was noted in each group. This finding suggests that increasing apical pressure in the lower torque settings has no effect on implant depth. A small trend was noted at 50 Ncm that when apical pressure was increased, the IP-PP distance increased; however, according to the ANOVA test, increased apical pressure had no statistically significant effect on implant platform depth for all three torque values. When comparing the torque value of the implant motor to the implant final torque setting with a manual wrench the findings suggest that the implant motor was properly calibrated and that inaccurate torque values delivered by the implant motor were not a direct cause of decreased implant depth. As mentioned previously the OSSTELL (ISQ) measurements were not included in the final analysis. To truly benefit from ISQ measurements a baseline ISQ needs to be taken at initial implant placement and then repeated at time of loading of implant to properly

compare change in implant stability over time. In this study only one ISQ measurement was taken at baseline.

CHAPTER 5: Conclusions

The study showed that the effect of increasing apical pressure did not cause a statistically significant difference in the depth of implant placement within a simulated osteotomy. Although, a trend was noted during the preset torque value of 50Ncm of an increased IP-PP distance as apical pressure of increased. Limitations to this study include in vitro design, the uniform density of the polymer cylinders does not mimic variable density of human bone, a limited number of apical pressures (weights) were tested, the taper of the implant remained constant throughout, and smooth surfaced implant were used. To truly determine if apical pressure does have an effect on implant depth modification to the study design to include materials that are similar to human bone density, roughened surface implants and a wider range of apical pressures.

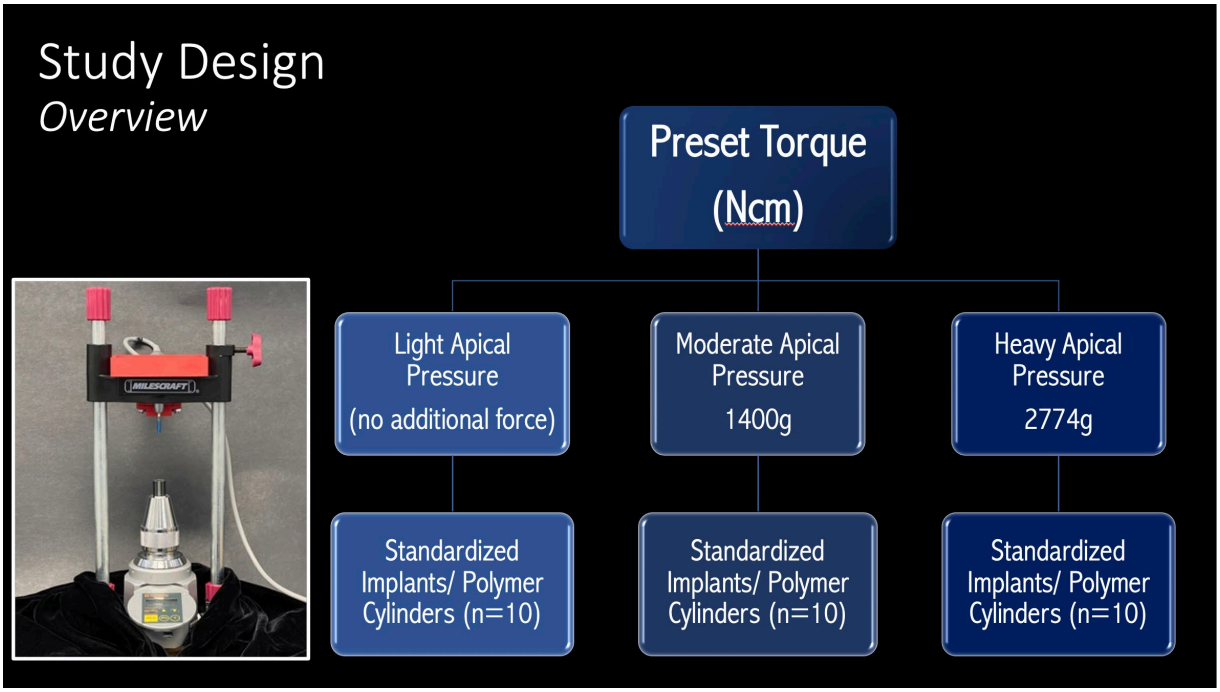

Figure 1. Study design overview. Three main groups for the study were created. Each group was designated by a set torque value for the implant motor. Each group were tested with light, moderate and heavy apical pressure using ten implant and ten polymers each.

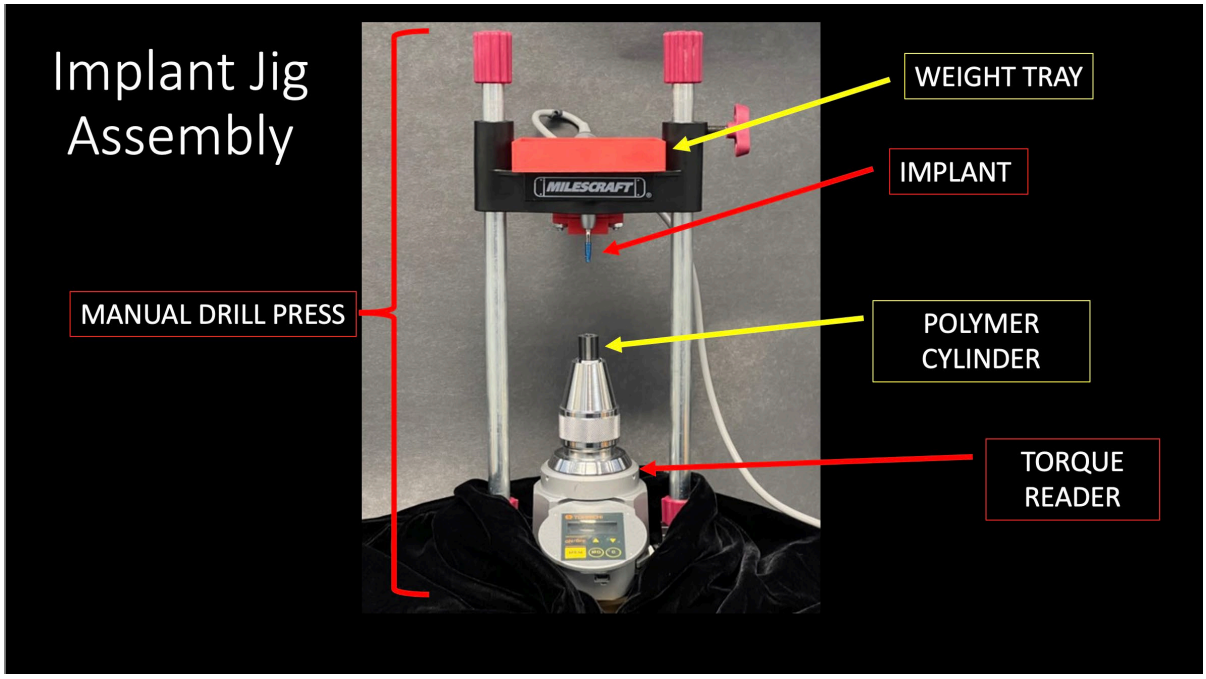

Figure 2. Implant Jig Assembly to include the main frame work comprised of a manual drill press, a cross bar with holds the implant hand piece and the weight tray, a torque reader and polymer cylinder.

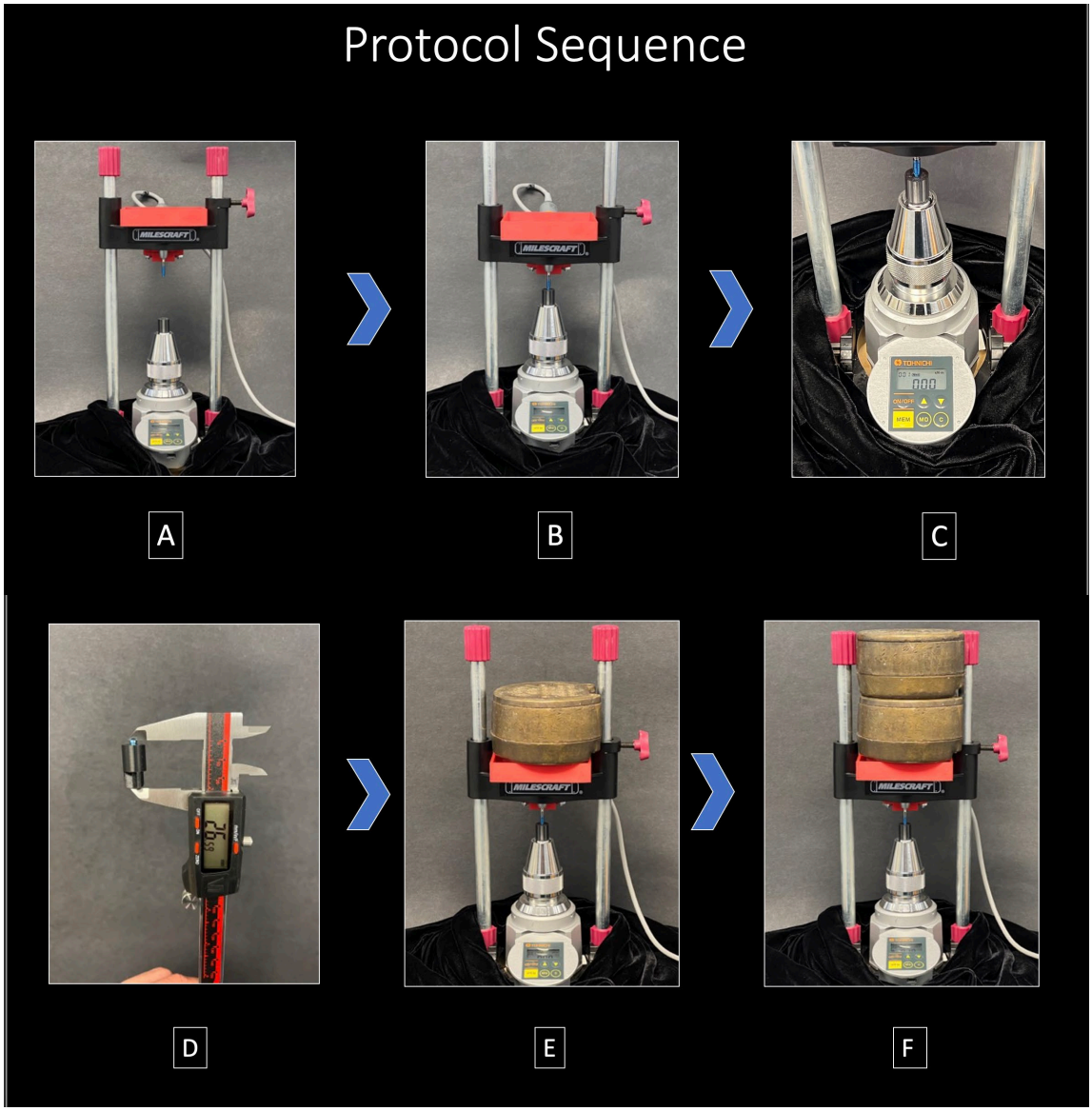

Figure 3. Protocol sequence (A) implant jib with implant attached to implant handpiece and polymer cylinder secured to the torque reader. (B) implant placed in contact with polymer cylinder; (C) Starting position with the torque reading zeroed out; (D) Digital caliper measuring the implant platform to the base of the polymer; (E) implant jig with metal denture flask representing “Moderate” weight; (F) implant jag with metal denture flask representing “Heavy” weight.

Figure 4. Hand Torque Wrench measuring the final torque value of the implant in the polymer to compare to the present torque value on the implant motor

Figure 5. Osstell™ sensor next to Smart Peg™ acquiring ISQ value

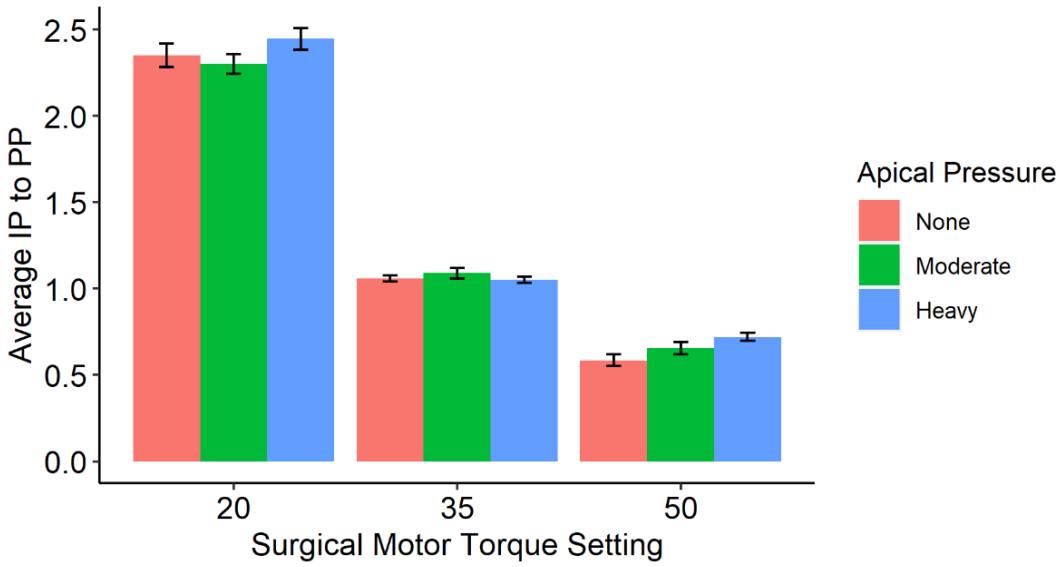

Figure 6. Average Insertion Torque Value at 20, 30 and 50 Ncm of implant motor torque setting

Table 1 Characteristics of Dependent Variables by Surgical Motor Torque Setting

Outcome	Surgical Motor Torque Setting		
	20, N = 30[1]	**35**, N = 30[1]	**50**, N = 30[1]
Torque meter (Ncm)	23 (1)	40 (1)	55 (1)
IP to PP (mm)	2.37 (0.20)	1.07 (0.07)	0.65 (0.11)
Torque wrench (Ncm)	20 (1)	35 (2)	48 (1)
Osstell (ISQ)	26 (3)	44 (27)	42 (27)

[1] Mean (SD)

Table 2: Characteristics of Dependent Variables by Apical Pressure

Outcome	Apical Pressure		
	None, N = 30[1]	**Moderate**, N = 30[1]	**Heavy**, N = 30[1]
Torque meter (Ncm)	40 (13)	39 (13)	39 (13)
IP to PP (mm)	1.33 (0.77)	1.35 (0.72)	1.41 (0.77)
Torque wrench (Ncm)	35 (12)	34 (12)	33 (13)
Osstell (ISQ)	58 (31)	27 (3)	27 (3)

[1] Mean (SD)

APPENDIX A

Surgical Motor Torque Setting (Ncm)		No additional apical pressure				Moderate apical pressure				Heavy apical pressure			
		IP to PP (mm)	Torque meter (Ncm)	Torque wrench (Ncm)	Osstell (ISQ)	IP to PP (mm)	Torque meter (Ncm)	Torque wrench (Ncm)	Osstell (ISQ)	IP to PP (mm)	Torque meter (Ncm)	Torque wrench (Ncm)	Osstell (ISQ)
20	1	2.48	23.45	22	22	2.58	22.8	18.75	28	2.62	22.65	17	20
	2	2.53	23.65	21.5	22	1.97	24.4	19.35	28	2.44	22.25	17.8	25
	3	2.56	23.1	19.35	20	2.26	22.9	20.95	28	2.71	22.8	19.75	25
	4	2.32	23.8	20.45	30	2.37	23.15	20.3	35	2.32	22.4	17.7	30
	5	2.39	23.35	20.85	28	2.25	23.25	19.95	22	2.21	22.7	17.55	25
	6	2.37	22.95	20.2	25	2.35	22.65	20.75	22	2.25	22.2	17.85	28
	7	2.44	24.1	21.15	28	2.45	22.75	20.2	28	2.72	21.95	18.1	25
	8	1.8	23.85	19.8	30	2.37	23.3	18.73	28	2.24	22.8	17.65	25
	9	2.26	24.45	20.9	25	2.05	23.35	19.3	25	2.52	22.5	17.9	28
	10	2.36	23.1	21.5	28	2.37	23.25	20.25	25	2.42	22	18.6	20
	Mean	2.351	23.58	20.77	25.8	2.302	23.18	19.853	26.9	2.445	22.425	17.99	25.1
	s.d.	0.214758262	0.480855719	0.825361873	3.552776692	0.180603925	0.497884413	0.783993339	3.754996671	0.192541482	0.316447292	0.739293957	3.212821536
35	1	1	42.35	34.45	88	1.08	39.55	34.05	35	1.17	39.25	32.4	28
	2	1.01	40.44	35.3	87	1.15	41.15	36.35	22	1.09	38.7	34.95	30
	3	1.05	41.3	35.5	87	1.02	38.75	34.6	25	1.02	38.95	33.95	30
	4	1	41.85	38.8	90	1.01	40.85	35.65	32	1.05	39.1	32.85	28
	5	1.15	42.4	37.5	89	1.12	40.9	37.8	25	1.04	38.25	33.9	28
	6	1.15	40.3	33.6	28	1.05	39.8	36.05	28	1	41.6	36.15	25
	7	1.09	40.55	37.8	89	1.32	39	33.5	25	1.08	39.8	35.45	28
	8	1.02	41.9	35.85	88	0.98	40.6	35.8	28	0.97	37.9	32.9	28
	9	1.03	41.15	35.65	87	1.06	38.95	34	25	1.04	38.7	35.2	28
	10	1.07	40.5	35.2	28	1.1	38.7	33.7	28	1.05	38.4	34.1	30
	Mean	1.057	41.274	35.965	76.1	1.089	39.825	35.15	27.3	1.051	39.065	34.185	28.3
	s.d.	0.05716448	0.811914062	1.598792947	25.37036767	0.096315454	0.972182539	1.398610421	3.831158804	0.054660569	1.040579433	1.240082883	1.494434118
50	1	0.39	55	48.2	90	0.63	56.45	48.7	25	0.72	54.25	47.35	25
	2	0.5	55.2	49.15	90	0.76	54.35	45.45	28	0.72	54.25	47.8	28
	3	0.53	55.6	48.1	35	0.49	56.15	48.5	25	0.79	54.25	47.45	25
	4	0.56	54.55	49.7	89	0.68	54.65	45.95	25	0.73	55	49.65	25
	5	0.72	58.15	50.02	89	0.71	54.85	46.05	22	0.57	54	47.45	28
	6	0.62	56.25	48	90	0.55	54.4	47.2	28	0.65	53.65	48.5	30
	7	0.76	56	46.05	90	0.8	53.9	47.95	25	0.67	54.6	47.85	28
	8	0.53	56.1	49.7	32	0.57	55.2	49.68	22	0.77	54.4	48.05	30
	9	0.67	55.75	47.8	32	0.56	55.7	51.05	28	0.83	53.85	48.6	28
	10	0.57	55.65	48.35	90	0.8	53.35	47.9	28	0.75	53.15	47.65	25
	Mean	0.585	55.825	48.507	72.7	0.655	54.9	47.843	25.6	0.72	54.14	48.035	27.2
	s.d.	0.110277428	0.970466669	1.18450224	27.41066297	0.111479943	0.984039295	1.756840915	2.366431913	0.074833148	0.514133575	0.70987088	2.043961296

IP: Implant platform

PP: Polymer platform

ISQ: Initial stability quotient

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