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Research Article

Measurement of Pressure in Orthognathic Surgery using Pressurex®

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Abstract

Purpose: Despite its importance, the measurement of pressure in orthognathic surgery often receives little attention. Pressurex® (SPL – Sensor Products LLC, USA) is one of a few pressure indicating sensor films that reveals pressure distribution and magnitude between any two contacting, mating or impacting surfaces, and is currently viewed as a golden standard for that purpose.
This study was designed to apply other alternative and innovative methods of measuring muscle area, volume, structure, function and fibre orientation to a situation where adaptation of muscle is pivotal to the success of a therapeutic approach.
Materials and Methods: Ten patients attending the combined orthodontic/orthognathic surgery clinic at the Clitrofa – Centro Médico, Dentário e Cirúrgico, in Trofa - Portugal were tested according to the following protocol: The pressure sensor film system was placed between the upper and lower dental arch, and the subjects were instructed to bite as forcefully as possible for about 3 seconds. The values were registered (T0) and the procedure was repeated after 10 minutes (T1), and after 1 month after surgery (T2). The occlusal pressure was measured by two different observers. The results have been measured by two different observers and the results analysis were performed using the Magics® RP software. These 10 patients were scheduled for a bimaxillary osteotomy involving a combination of maxillary Le Fort I impaction procedure coupled with a sagittal split advancement of the mandible.
Conclusions: Significant statistical differences in the mean bite pressure (psi) have been detected between pre-op (Times 0 and 1) and post-op (Time 2) periods for the film pressure areas Q2/P2, Q3/P3 and Q4/P4, irrespective of the Examiner (C or F) ($p < 0,05$). Interestingly, these differences in the mean bite pressure (psi) at different times are concentrated in the anterior and mid region of the maxilla/ mandible, whereas in the posterior region of the maxilla/ mandible (Q1/P1 and Q5/P5), no significant statistical differences have been detected throughout time ($p > 0,05$).

Keywords

Orthognathic Surgery, Masseter Muscle, Pressure Measurement, Pressurex®

Declaration of Conflicting Interest

The authors declare that they have no conflict of interest.

Introduction:

Orthodontic and surgical technical advances in recent years have resulted in treatment opportunities for a whole range of craniofacial skeletal disorders either in the adolescent or adult patients. In the growing child these can include myofunctional orthodontic appliance therapy or distraction osteogenesis procedures, whilst in the adult the mainstay approach revolves around orthognathic surgery.

Research evidence suggests that in those cases requiring orthognathic surgery, the stability of the result depends upon such factors as the direction and extent of the surgical move of the facial skeleton, the method of surgical fixation applied and the operative technique employed. Yet, even when the best evidence-based practice is followed, there remains a significant proportion of cases where the surgical outcome (stability) is both unexpected and undesirable1.

Our understanding of the biological adaptive mechanisms occurring in both the hard and soft tissues of the face, and which are fundamental to all these treatment approaches remains, at a rather basic level. There is little information concerning the distribution of bite force on the dental arch during clenching in normal dentitions2.

Bite force has been used to evaluate masticatory function in patients before and after orthognathic surgery3,4,5,6,7. Usually, it has been measured with a custom bite force transducer5,6,8.

Pressure is a critical variable in many converting operations. Tactile pressure-sensor films are an accurate, efficient, and inexpensive method to determine pressure. These films offer the converting industry an opportunity to determine both the distribution and magnitude of most operations where pressure is important.

Pressurex® System:

Pressurex® (SPL – Sensor Products LLC, USA) is a pressure indicating sensor film that reveals pressure distribution and magnitude between any two contacting, mating or impacting surfaces. Pressurex® consists of a thin mylar film (4 to 8 mils) that contains a layer of tiny microcapsules. Because Pressurex® is extremely thin, it is ideal for invasive intolerant environments and curvaceous surfaces that are not accessible to electronic pressure transducers.

The application of force upon the film causes the microcapsules to rupture, producing an instantaneous and permanent high resolution "topographical" map of pressure variations across the contact area. Simply place sensor film, between any two surfaces that touch, mate or impact. Apply pressure, release it; immediately the film reveals a profile of the pressure distribution that occurred between the surfaces. The colour intensity of the image created is directly related to the amount of pressure applied, the greater the pressure, the more intense colour.

During use, visual comparison of colour intensity to a colour correlation chart provides a pressure-measurement reading that is accurate to ±10%. With the use of optical measuring systems, the pressure reading may be more accurately quantified to ±2%. Use of a pressure-sensor film is an alternative to strain gauges and pressure transducers with accompanying electronic equipment. Various films are offered, with some in a range of sensitivities to accommodate varying amounts of pressure. Pressure ranges can start as low as 2-20 psi (0.14-1.4 Kg/cm2) and go as high as 7,100-18,500 psi (500-1,300 Kg/cm2). Roll and sheet sizes are available with active shelf life varying, but it can be as much as two years. Normal temperature application is 41 deg F to 95 deg F (5 deg C to 35 deg C), but some material can withstand much higher temperatures for brief exposures.

Density of coloration was measured with a colour image scanner (GT-1,000, Seiko-Epson, Co., Japan) in 256 grades, and converted to a pressure scale with a calibration curve. Image resolution of the scanner was 100 dpi. Load was obtained by integrating the pressure in the coloured area.

Materials and Methods:

Ten patients attending the combined orthodontic/orthognathic surgery clinic at the Clitrofa – Centro Médico, Dentário e Cirúrgico, in Trofa - Portugal were tested according to the following protocol: In order to provide adequate bite registration of the patients a new metal framework in a horseshoe-shaped form was developed. The metallic structure was designed based on the contour of the dental arch, occupying the external contour of the same without interfering with the occlusion. It was intended to support the Pressurex® film and contained 5 metallic re-intrances that held it during the patient's biting process and a handle to facilitate all the process.

The pressure sensor film system was placed between the upper and lower dental arch, and the subjects were instructed to bite as forcefully as possible for about 3 seconds. The values were registered (T0) and the procedure was repeated after 10 minutes (T1), and after 1 month after surgery (T2). The occlusal pressure was measured by two different observers. The results have been measured by two different observers and the results analysis were performed using the Magics® RP software.

The five areas of analysis were distributed in the following order: Q1: right maxillary second pre-molar and right maxillary first molar between 1st and 4th quadrants; Q2: right maxillary canine and right maxillary first pre-molar between 1st and 4th quadrants; Q3: right and left maxillary central incisors and right and left maxillary lateral incisors area; Q4: left maxillary second pre-molar and left maxillary first molar between 2nd and 3rd quadrants, and finally Q5: left maxillary canine and left maxillary first pre-

molar between 2nd and 3rd quadrants.

These 10 patients were scheduled for a bimaxillary osteotomy involving a combination of maxillary Le Fort I impaction procedure coupled with a sagittal split advancement of the mandible.

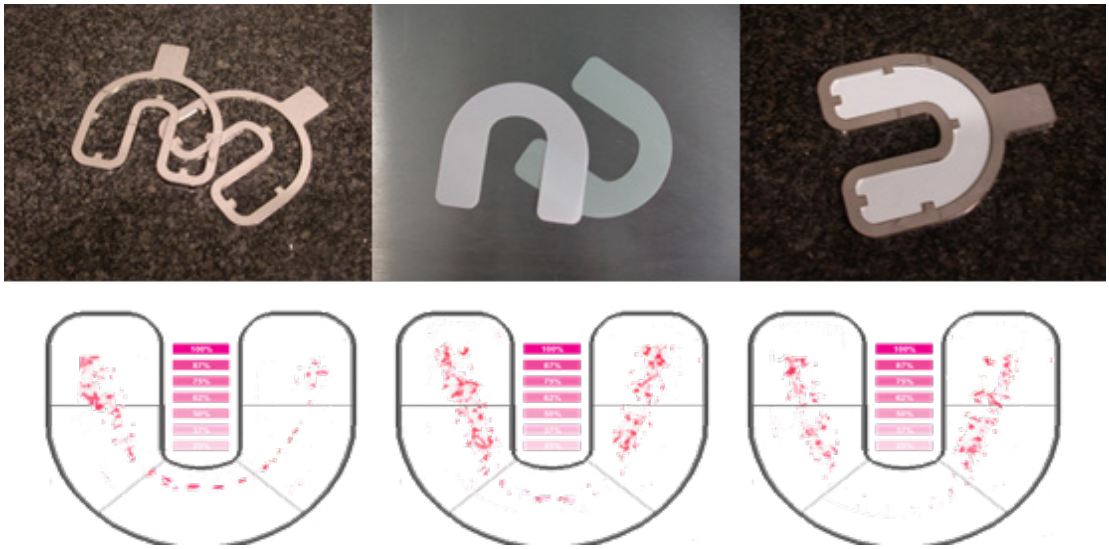

Figure1: Clinical application of the metal framework containing the Pressurex® film. Biting area and pressure distribution in 5 areas

The experimental design devised for this study is depicted in Figure 2, comprising a combination of different examiners, film pressure areas and times of measurement.

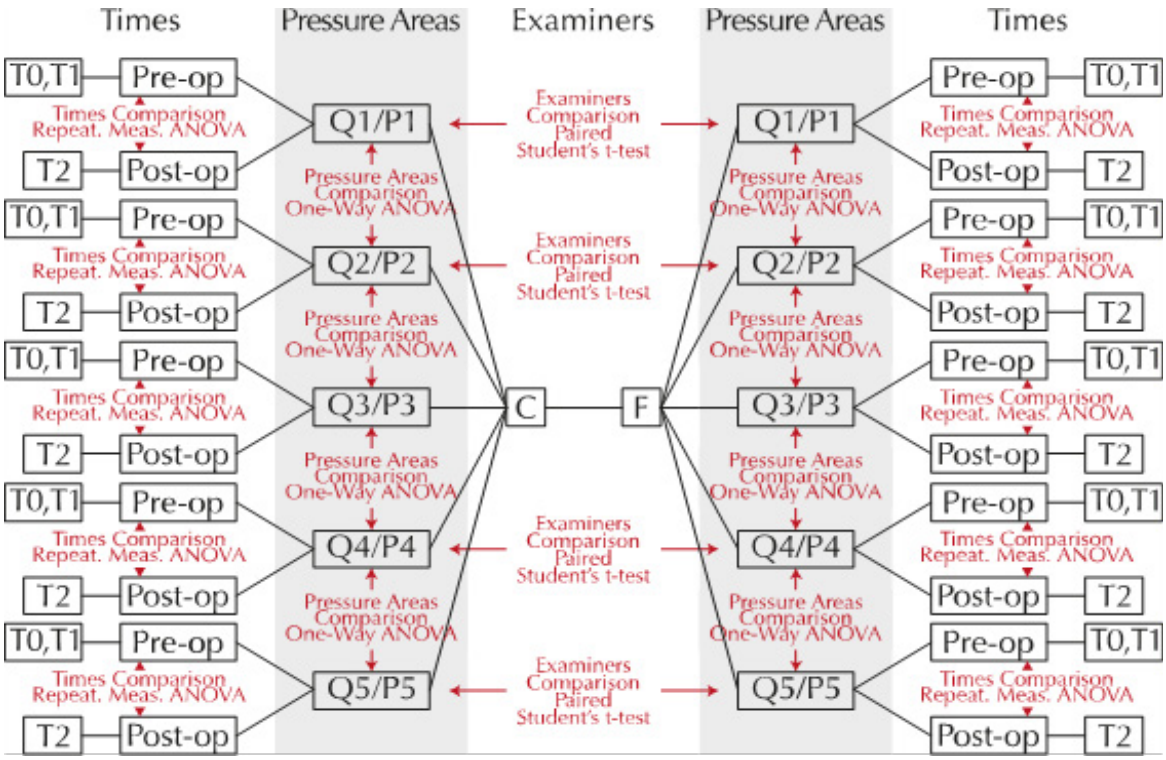

Figure 2: Experimental design used for the measurement of film pressure areas. The study involved the contribution of two independent examiners (F and C), that measured the bite pressure (psi) in five different film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) at three different time moments (Time 0, Time 1 and Time 2).

IBM® SPSS® version 25 was used to analyze the data obtained. The data were first tested to ensure they conformed to a normal distribution by using the Kolmogorov-Smirnov test, the Shapiro-Wilks test or by determining the values of skewness (acceptable values for normality between -2 and +2) and kurtosis (acceptable values for normality between -2 and +2). Descriptive statistics included the arithmetic mean ($\bar{x}$), standard deviation (SD), and standard error of the mean (SE), as well as the 95% confidence interval (95% CI). Where the data were not normally distributed, the median and the inter-quartile range (IQR) were noted.

In those situations where the data were normally distributed and the variances were constant, comparative analysis involved either the unpaired or paired two-tailed Student's t test. Multiple comparisons were made using the One-Way Analysis of Variance (ANOVA) or Repeated Measure Analysis of Variance (ANOVA) depending if the data were, respectively, unpaired or paired.

Post-Hoc Gabriel test and post-hoc Bonferroni test were used, respectively for One-Way ANOVA and Repeated Measures ANOVA, to identify the pairs where the significant statistical differences were located.

Where the requirements for parametric statistical analysis were not met, the data were analyzed using either the Wilcoxon Signed Rank (U) test for paired data or the Mann-Whitney (U) test for unpaired data as appropriate. Comparison between three or more groups were made using the Kruskal-Wallis (H) or the Friedman (H) test depending if the data were, respectively, unpaired or paired.

The minimum level of significance (α level) accepted throughout the development studies was 0.05 (*), considered to be "moderately significant". Levels of 0.01 (**) were considered as "significant" and 0.001 (***) designated as "highly significant". A lack of statistical significance was designated as (ns).

Comparison A – Testing the Differences between Examiners (F versus C)

Research question: Are there any significant statistical differences in the mean bite pressure (psi) measured by Examiner F and Examiner C in the same experimental conditions?

H0: There are no significant statistical differences in the mean bite pressure (psi) measured by Examiner F and Examiner C in the same experimental conditions.

H1: There are significant statistical differences in the mean bite pressure (psi) measured by Examiner F and Examiner C in the same experimental conditions.

Comparison B – Testing the Differences between Times (T0 versus T1 versus T2)

Research question: Are there any significant statistical differences in the mean bite pressure (psi) measured between moments Time 0, Time 1 and Time 2 in the same experimental conditions?

H0: There are no significant statistical differences in the mean bite pressure (psi) measured at moments Time 0, Time 1 and Time 2 in the same experimental conditions.

H1: There are significant statistical differences in the mean bite pressure (psi) measured at moments Time 0, Time 1 and Time 2 in the same experimental conditions.

Comparison C – Testing the Differences between Film Pressure Areas (Q1/P1 versus Q2/P2 versus Q3/P3 versus Q4/P4 versus Q5/P5)

Research question: Are there any significant statistical differences in the mean bite pressure (psi) measured by film pressure areas Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5 in the same experimental conditions?

H0: There are no significant statistical differences in the mean bite pressure (psi) measured by sensors Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5 in the same experimental conditions.

H1: There are significant statistical differences in the mean bite pressure (psi) measured by sensors Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5 in the same experimental conditions.

Results:

Table I presents the experimental data for the measurement of mean bite pressure (psi) by Pressurex® system, as well as its SD and variance values.

Variable	Mean (psi)	SD (psi)	Variance (psi2)
P1_F_T0	790,427	343,272	117835,719
P1_F_T1	790,427	343,272	117835,719
P1_F_T2	839,909	318,445	101407,316
P1_C_T0	790,427	343,272	117835,719
P1_C_T1	790,427	343,272	117835,719
P1_C_T2	839,909	318,445	101407,316
P2_F_T0	684,822	364,488	132851,739
P2_F_T1	684,822	364,488	132851,739
P2_F_T2	790,427	340,656	116046,767
P2_C_T0	1155,830	201,272	40510,513
P2_C_T1	1122,842	192,534	37069,204
P2_C_T2	775,202	328,271	107761,982
P3_F_T0	40,000	51,640	2666,667
P3_F_T1	40,000	51,640	2666,667
P3_F_T2	282,476	139,769	19535,323
P3_C_T0	40,000	51,640	2666,667
P3_C_T1	40,000	51,640	2666,667
P3_C_T2	283,745	160,185	25659,107
P4_F_T0	581,903	340,854	116181,760
P4_F_T1	581,903	340,854	116181,760
P4_F_T2	742,214	315,706	99670,246
P4_C_T0	660,566	406,047	164874,351
P4_C_T1	613,622	375,063	140672,528
P4_C_T2	688,777	328,546	107942,470
P5_F_T0	931,259	275,139	75701,369
P5_F_T1	931,259	275,139	75701,369
P5_F_T2	916,034	221,200	48929,258
P5_C_T0	931,259	275,139	75701,369
P5_C_T1	931,259	275,139	75701,369
P5_C_T2	932,528	241,935	58532,394

Table I: Values of bite pressure (psi) measured at the different experimental conditions shown in Figure 1.

Comparison A – Testing the Differences between Examiners (F versus C)

The statistical comparison of examiners F and C regarding the measurement of mean bite pressure (psi) was performed using a Paired Student's t-test for the five different film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) at the three different time moments (Time 0, Time 1 and Time 2) (Figure 3 and Table 2).

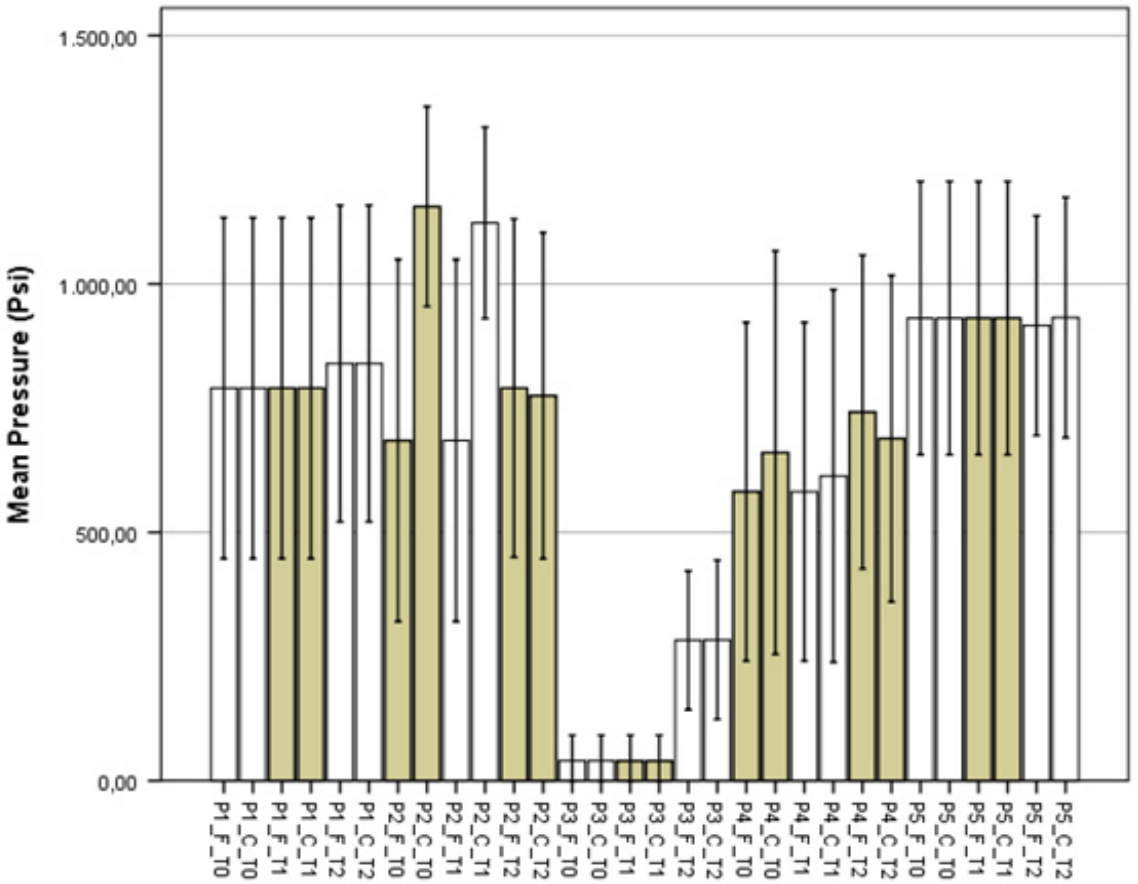

Figure 3: Mean bite pressure (psi) measured by Examiner F and Examiner C in five different film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) at three different time moments (Time 0, Time 1 and Time 2). Error bars represent standard deviation values.

Examiners Comparison	Mean Diference	Standard Deviation of Differences	Degrees of Freedom (df)	Test statistic from Paired t-test	P-value from Paired t-test
Examiner F versus Examiner C, P1, Time 0	-471,008	471,83052	9	-	-
Examiner F versus Examiner C, P1, Time 1	-438,020	488,60659	9	-	-
Examiner F versus Examiner C, P1, Time 2	15,225	86,42414	9	-	-
Examiner F versus Examiner C, P2, Time 0	-1,269	74,81025	9	-3,157	0,012*
Examiner F versus Examiner C, P2, Time 1	-78,663	152,34482	9	-2,835	0,020*
Examiner F versus Examiner C, P2, Time 2	-31,719	98,14074	9	0,557	0,591
Examiner F versus Examiner C, P3, Time 0	53,437	87,55778	9	-	-
Examiner F versus Examiner C, P3, Time 1	-16,494	52,15861	9	-	-
Examiner F versus Examiner C, P3, Time 2	-471,008	471,83052	9	-0,054	0,958
Examiner F versus Examiner C, P4, Time 0	-438,020	488,60659	9	-1,633	0,137
Examiner F versus Examiner C, P4, Time 1	15,225	86,42414	9	-1,022	0,333
Examiner F versus Examiner C, P4, Time 2	-1,269	74,81025	9	1,930	0,086
Examiner F versus Examiner C, P5, Time 0	-78,663	152,34482	9	-	-
Examiner F versus Examiner C, P5, Time 1	-31,719	98,14074	9	-	-
Examiner F versus Examiner C, P5, Time 2	53,437	87,55778	9	-1,000	0,343

Table II: Statistical parameters obtained in the Paired Student's t-test for the comparison of examiners F and C when measuring the mean bite pressure (psi) in different experimental conditions.

* moderately significant to 0.05 level; ** significant to 0.01 level; *** highly significant to 0.001 level.

Most of the results show no significant statistical differences in the mean bite pressure (psi) measured by Examiner F and Examiner C, when the measurement is made in the same experimental conditions.

Comparison B – Testing the Differences between Times (T0 vs T1 vs T2)

The statistical comparison between the three-time moments (Time 0, Time 1 and Time 2) regarding the measurement of mean bite pressure (psi) was performed using a Repeated Measures ANOVA for the five film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) and the different examiners F and C (Figure 4 and Table III).

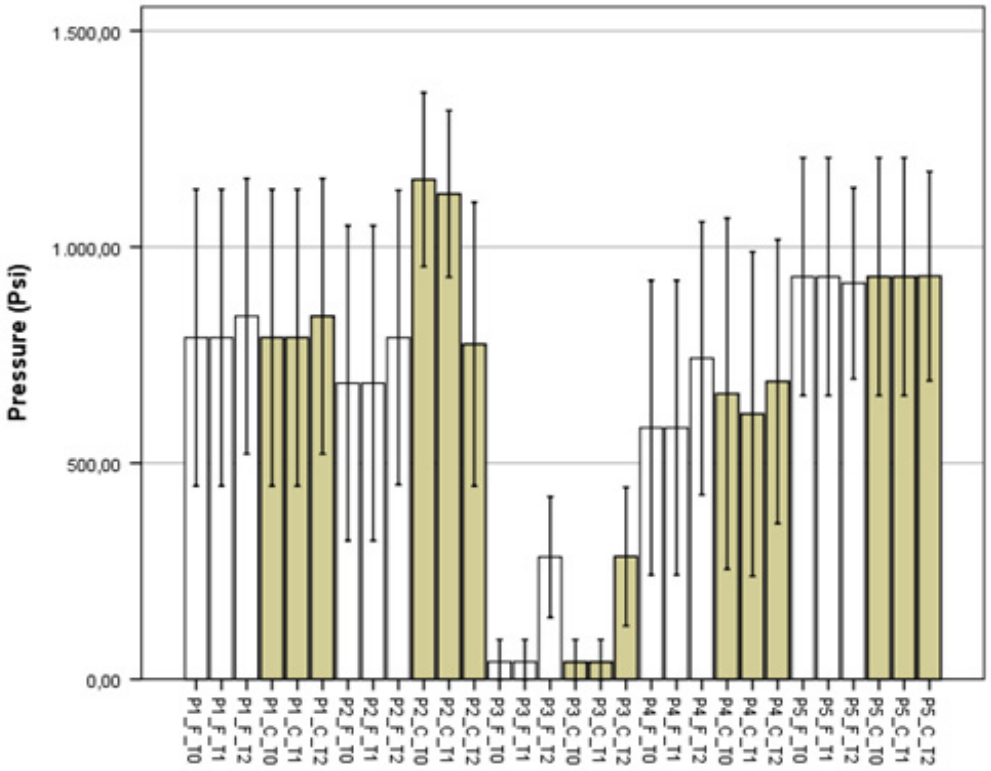

Figure 4: Mean bite pressure (psi) measured in three-time moments (Time 0, Time 1 and Time 2) by Examiner F and Examiner C in five different film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5). Error bars represent standard deviation values.

Times Comparison	Degrees of Freedom (df)	Test statistic (F)	P-value (Sig)
Time 0 vs Time 1 vs Time 2, Examiner F, P1	2, 18	2,129	0,148
Time 0 vs Time 1 vs Time 2, Examiner C, P1	2, 18	2,129	0,148
Time 0 vs Time 1 vs Time 2, Examiner F, P2	2, 18	7,734	0,004**
Time 0 vs Time 1 vs Time 2, Examiner C, P2	2, 18	6,021	0,010*
Time 0 vs Time 1 vs Time 2, Examiner F, P3	2, 18	47,605	0,000***
Time 0 vs Time 1 vs Time 2, Examiner C, P3	2, 18	32,456	0,000***
Time 0 vs Time 1 vs Time 2, Examiner F, P4	2, 18	12,676	0,000***
Time 0 vs Time 1 vs Time 2, Examiner C, P4	2, 18	1,682	0,214
Time 0 vs Time 1 vs Time 2, Examiner F, P5	2, 18	0,277	0,761
Time 0 vs Time 1 vs Time 2, Examiner C, P5	2, 18	0,001	0,999

Table III: Statistical parameters obtained in the Repeated Measures ANOVA for the comparison of time moments (Time 0, Time 1 and Time 2) when measuring the mean bite pressure (psi) in different experimental conditions.

* moderately significant to 0.05 level; ** significant to 0.01 level; *** highly significant to 0.001 level.

Significant statistical differences in the mean bite pressure (psi) have been detected among different times (Time 0, Time 1 and Time 2) for the film pressure areas Q2/P2, Q3/P3 and Q4/P4, irrespective of the Examiner (C or F) ($p < 0,05$).

Because Repeated Measures ANOVA only gives information about the presence of differences, not specifying where these differences are located, a Post-Hoc Bonferroni test was used to perform pairwise comparisons between the times, and these results are represented in Table IV.

Independent Variable			Mean Difference (I-J)	Std. Error	Sig.
F_Q2/P2	T0	T1	0,000	0,000	-
		T2	-105,605	37,974	0,064
	T1	T0	0,000	0,000	-
		T2	-105,605	37,974	0,064
	T2	T0	105,605	37,974	0,064
		T1	105,605	37,974	0,064
C_Q2/P2	T0	T1	32,988	21,992	0,504
		T2	380,628	146,431	0,086
	T1	T0	-32,988	21,992	0,504
		T2	347,640	149,635	0,136
	T2	T0	-380,628	146,431	0,086
		T1	-347,640	149,635	0,136
F_Q3/P3	T0	T1	0,000	0,000	-
		T2	-242,476	35,143	0,000***
	T1	T0	0,000	0,000	-
		T2	-242,476	35,143	0,000***
	T2	T0	242,476	35,143	0,000***
		T1	242,476	35,143	0,000***
C_Q3/P3	T0	T1	0,000	0,000	-
		T2	-243,745	42,784	0,001**
	T1	T0	0,000	0,000	-
		T2	-243,745	42,784	0,001**
	T2	T0	243,745	42,784	0,001**
		T1	243,745	42,784	0,001**
F_Q4/P4	T0	T1	0,000	0,000	-
		T2	-160,311	45,027	0,018*
	T1	T0	0,000	0,000	-
		T2	-160,311	45,027	0,018*
	T2	T0	160,311	45,027	0,018*
		T1	160,311	45,027	0,018*

Table IV: Statistical parameters obtained in the Post-Hoc Bonferroni test for the comparison of Times (Time 0, Time 1 and Time 3) when measuring the mean bite pressure (psi) in different experimental conditions.

* moderately significant to 0.05 level; ** significant to 0.01 level; *** highly significant to 0.001 level.

Comparison C – Testing the Differences between Film Pressure Areas (Q1/P1 versus Q2/P2 versus Q3/P3 versus Q4/P4 versus Q5/P5)

The statistical comparison between the five pressure sensor film areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) regarding the measurement of mean bite pressure (psi) was performed using a One-Way ANOVA for the different examiners F and C at the three different time moments (Time 0, Time 1 and Time 2) (Figure 5 and Table V).

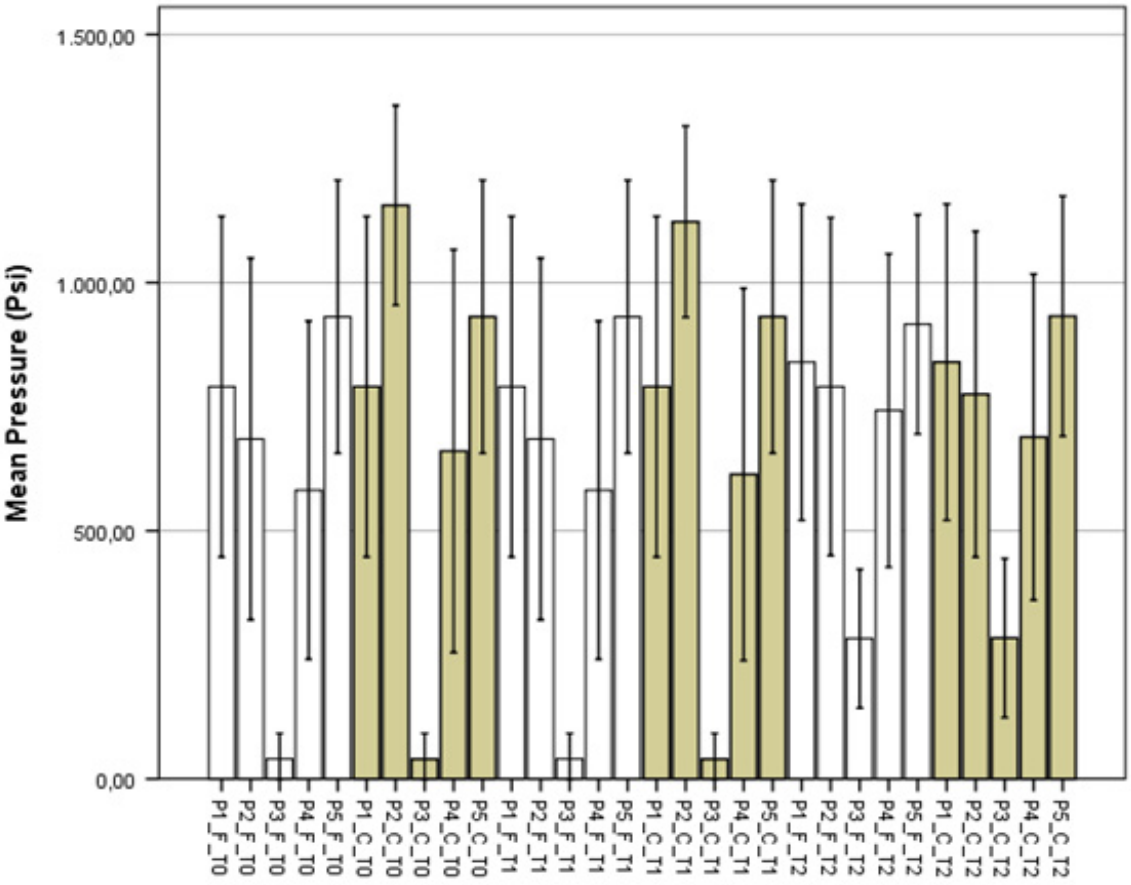

Figure 5: Mean bite pressure (psi) measured in five pressure sensor film areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) by Examiner F and Examiner C at three different time moments (Time 0, Time 1 and Time 2). Error bars represent standard deviation values.

Sensors Comparison		Sum of Squares	Degrees of Freedom (df)	Mean Square	Test statistic (F)	P-value (Sig)
P1 vs P2 vs P3 vs P4 vs P5, Examiner F, Time 0	Between Groups	4669558,035	4	1167389,509	13,110	0,000***
	Within Groups	4007135,280	45	89047,451		
	Total	8676693,315	49	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner F, Time 1	Between Groups	4669558,035	4	1167389,509	13,110	0,000***
	Within Groups	4007135,280	45	89047,451		
	Total	8676693,315	49	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner F, Time 2	Between Groups	2495206,674	4	623801,669	8,089	0,000***
	Within Groups	3470300,193	45	77117,782		
	Total	5965506,867	49	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner C, Time 0	Between Groups	7053744,369	4	1763436,092	21,956	0,000***
	Within Groups	3614297,563	45	80317,724		
	Total	10668041,932	49	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner C, Time 1	Between Groups	6835135,988	4	1708783,997	22,848	0,000***
	Within Groups	3365509,385	45	74789,097		
	Total	10200645,372	49	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner C, Time 2	Between Groups	2526120,274	4	631530,069	7,868	0,000***
	Within Groups	3611729,427	45	80260,654		
	Total	6137849,702	49	-		

Table V: Statistical parameters obtained in the One-Way ANOVA for the comparison of film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) when measuring the mean bite pressure (psi) in different experimental conditions.
* moderately significant to 0.05 level; ** significant to 0.01 level; *** highly significant to 0.001 level.

There are significant statistical differences in the mean bite pressure (psi) measured by the different film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5), when the measurement if made in the same experimental conditions.

Because One-Way ANOVA only gives information about the presence of differences, not specifying where these differences are located, a Post-Hoc Gabriel test was used to perform pairwise comparisons between the film pressure areas, and these results are represented in Table VI.

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
F_T0	Q1/P1	Q2/P2	105,605	133,452	0,995
		Q3/P3	750,427	133,452	0,000***
		Q4/P4	208,524	133,452	0,714
		Q5/P5	-140,832	133,452	0,963
	Q2/P2	Q1/P1	-105,605	133,452	0,995
		Q3/P3	644,822	133,452	0,000***
		Q4/P4	102,919	133,452	0,996
		Q5/P5	-246,437	133,452	0,502
	Q3/P3	Q1/P1	-750,427	133,452	0,000***
		Q2/P2	-644,822	133,452	0,000***
		Q4/P4	-541,903	133,452	0,002**
		Q5/P5	-891,259	133,452	0,000***
	Q4/P4	Q1/P1	-208,524	133,452	0,714
		Q2/P2	-102,919	133,452	0,996
		Q3/P3	541,903	133,452	0,002**
		Q5/P5	-349,356	133,452	0,110
	Q5/P5	Q1/P1	140,832	133,452	0,963
		Q2/P2	246,437	133,452	0,502
		Q3/P3	891,259	133,452	0,000***
		Q4/P4	349,356	133,452	0,110
F_T1	Q1/P1	Q2/P2	105,605	133,452	0,995
		Q3/P3	750,427	133,452	0,000***
		Q4/P4	208,524	133,452	0,714
		Q5/P5	-140,832	133,452	0,963
	Q2/P2	Q1/P1	-105,605	133,452	0,995
		Q3/P3	644,822	133,452	0,000***
		Q4/P4	102,919	133,452	0,996
		Q5/P5	-246,437	133,452	0,502
	Q3/P3	Q1/P1	-750,427	133,452	0,000***
		Q2/P2	-644,822	133,452	0,000***
		Q4/P4	-541,903	133,452	0,002**
		Q5/P5	-891,259	133,452	0,000***
	Q4/P4	Q1/P1	-208,524	133,452	0,714
		Q2/P2	-102,919	133,452	0,996
		Q3/P3	541,903	133,452	0,002**
		Q5/P5	-349,356	133,452	0,110
	Q5/P5	Q1/P1	140,832	133,452	0,963
		Q2/P2	246,437	133,452	0,502
		Q3/P3	891,259	133,452	0,000***
		Q4/P4	349,356	133,452	0,110

F_T2	Q1/P1	Q2/P2	49,482	124,192	1,000
		Q3/P3	557,433	124,192	0,000***
		Q4/P4	97,695	124,192	0,996
		Q5/P5	-76,125	124,192	0,999
	Q2/P2	Q1/P1	-49,482	124,192	1,000
		Q3/P3	507,951	124,192	0,002**
		Q4/P4	48,213	124,192	1,000
		Q5/P5	-125,607	124,192	0,972
	Q3/P3	Q1/P1	-557,433	124,192	0,000***
		Q2/P2	-507,951	124,192	0,002**
		Q4/P4	-459,738	124,192	0,006**
		Q5/P5	-633,558	124,192	0,000***
	Q4/P4	Q1/P1	-97,695	124,192	0,996
		Q2/P2	-48,213	124,192	1,000
		Q3/P3	459,738	124,192	0,006**
		Q5/P5	-173,820	124,192	0,822
	Q5/P5	Q1/P1	76,125	124,192	0,999
		Q2/P2	125,607	124,192	0,972
		Q3/P3	633,558	124,19	0,000***
		Q4/P4	173,820	124,192	0,822

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
C_T0	Q1/P1	Q2/P2	-365,403	126,742	0,057
		Q3/P3	750,427	126,742	0,000***
		Q4/P4	129,861	126,742	0,970
		Q5/P5	-140,832	126,742	0,949
	Q2/P2	Q1/P1	365,403	126,742	0,057
		Q3/P3	1115,830	126,742	0,000***
		Q4/P4	495,264	126,742	0,003**
		Q5/P5	224,571	126,742	0,558
	Q3/P3	Q1/P1	-750,427	126,742	0,000***
		Q2/P2	-1115,830	126,742	0,000***
		Q4/P4	-620,566	126,742	0,000***
		Q5/P5	-891,259	126,742	0,000***
	Q4/P4	Q1/P1	-129,861	126,742	0,970
		Q2/P2	-495,264	126,742	0,003**
		Q3/P3	620,566	126,742	0,000***
		Q5/P5	-270,693	126,742	0,309
	Q5/P5	Q1/P1	140,832	126,742	0,949
		Q2/P2	-224,571	126,742	0,558
		Q3/P3	891,259	126,742	0,000***
		Q4/P4	270,693	126,742	0,309

C_T1	Q1/P1	Q2/P2	-332,415	122,302	0,087
		Q3/P3	750,427	122,302	0,000***
		Q4/P4	176,805	122,302	0,793
		Q5/P5	-140,832	122,302	0,937
	Q2/P2	Q1/P1	332,415	122,302	0,087
		Q3/P3	1082,842	122,302	0,000***
		Q4/P4	509,220	122,302	0,001**
		Q5/P5	191,583	122,302	0,711
	Q3/P3	Q1/P1	-750,427	122,302	0,000***
		Q2/P2	-1082,842	122,302	0,000***
		Q4/P4	-573,622	122,302	0,000***
		Q5/P5	-891,259	122,302	0,000***
	Q4/P4	Q1/P1	-176,805	122,302	0,793
		Q2/P2	-509,220	122,302	0,001**
		Q3/P3	573,622	122,302	0,000***
		Q5/P5	-317,637	122,302	0,116
	Q5/P5	Q1/P1	140,832	122,302	0,937
		Q2/P2	-191,583	122,302	0,711
		Q3/P3	891,259	122,302	0,000***
		Q4/P4	317,637	122,302	0,116
C_T2	Q1/P1	Q2/P2	64,707	126,697	1,000
		Q3/P3	556,164	126,697	0,001**
		Q4/P4	151,132	126,697	0,923
		Q5/P5	-92,619	126,697	0,998
	Q2/P2	Q1/P1	-64,707	126,697	1,000
		Q3/P3	491,457	126,697	0,003**
		Q4/P4	86,425	126,697	0,999
		Q5/P5	-157,326	126,697	0,903
	Q3/P3	Q1/P1	-556,164	126,697	0,001**
		Q2/P2	-491,457	126,697	0,003**
		Q4/P4	-405,032	126,697	0,025*
		Q5/P5	-648,783	126,697	0,000***
	Q4/P4	Q1/P1	-151,132	126,697	0,923
		Q2/P2	-86,425	126,697	0,999
		Q3/P3	405,032	126,697	0,025*
		Q5/P5	-243,751	126,697	0,446
	Q5/P5	Q1/P1	92,619	126,697	0,998
		Q2/P2	157,326	126,697	0,903
		Q3/P3	648,783	126,697	0,000***
		Q4/P4	243,751	126,697	0,446

Table VI: Statistical parameters obtained in the Post-Hoc Gabriel test for the comparison of film pressure areas (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) when measuring the mean bite pressure (psi) in different experimental conditions.
* moderately significant to 0.05 level; ** significant to 0.01 level; *** highly significant to 0.001 level.

Discussion

Comparison A – Testing the Differences between Examiners (F vs C)

The few differences detected between Examiners (F versus C) were observed at Time 0 and Time 1 of measurement for the P2 film pressure area, probably due to small discrepancies in the experimental methodology. The overall results seem to indicate that the choice of examiner is not a variable that greatly affects the mean bite pressure (psi) measured by PressureX® pressure indicating sensor film, although special attention must be given for the standardization/homogenisation of the experimental methodology used, in order to avoid the differences detected among different examiners.

Comparison B – Testing the Differences between Times (T0 vs T1 vs T2)

The variations in the mean bite pressure (psi) at different times (Time 0 versus Time 1 versus Time 2) are concentrated in the anterior and mid region of the maxillae/ mandibulae, whereas in the posterior region of the maxillae/ mandibulae (Q1/P1 and Q5/P5), no significant statistical differences have been detected throughout time ($p > 0,05$). These differences have also been identified between Time 2 (1 month after surgery) and Times 0 and 1 (prior to surgery) in the film pressure area P3/Q3 located in the anterior region of the maxillae/mandibulae. Given the nature of the surgical procedure performed in the 10 patients – a bimaxillary osteotomy involving a combination of maxillary Le Fort I impaction procedure coupled with a sagittal split advancement of the mandible – it was expected that it would reflect in the mean pressure (psi) measured in the anterior region of the maxillae/mandibulae, as now it is statistically demonstrated.

Comparison C – Testing the Differences between Film Pressure Areas (Q1/P1 vs Q2/P2 vs Q3/P3 vs Q4/P4 vs Q5/P5)

Regarding the possible differences between film pressure areas (Q1/P1 vs Q2/P2 vs Q3/P3 vs Q4/P4 vs Q5/P5) for the same Examiner (F or C) and the same time moment (Time 0, Time 1 or Time 2), the inferential tests do confirm their existence ($p < 0,05$).

Post-Hoc Gabriel Test has determined that the significant statistical differences observed between the different film pressure areas mainly involve the film pressure area Q3/P3, when compared with the remaining film pressure areas ($p < 0,05$).

When the pairs of film pressure areas don't involve Q3/P3, almost no significant statistical differences are identifiable ($p > 0,05$), meaning that the best film pressure area to evaluate the efficacy of a bimaxillary osteotomy throughout time should be the anterior region of the maxillae/mandibulae.

Conclusions

The results show little significant statistical differences in the mean bite pressure (psi) between examiners, when the measurement is made in the same experimental conditions. The few differences observed ($p < 0,05$) were detected at Time 0 and Time 1 of measurement for the P2 film pressure area, probably due to small discrepancies in the experimental methodology used.

Significant statistical differences in the mean bite pressure (psi) have been detected between pre-op (Times 0 and 1) and post-op (Time 2) periods for the film pressure areas Q2/P2, Q3/P3 and Q4/P4, irrespective of the Examiner (C or F) ($p < 0,05$). Interestingly, these differences in the mean bite pressure (psi) at different times are concentrated in the anterior and mid region of the maxilla/ mandible, whereas in the posterior region of the maxilla/ mandible (Q1/P1 and Q5/P5), no significant statistical differences have been detected throughout time ($p > 0,05$).

The overall results presented for PressureX® pressure indicating sensor film show that this device can be successfully used for quantitative and qualitative evaluation of bite pattern, especially if the sensor film is placed in the anterior region of maxilla/mandible (i.e., in the film pressure area Q3/P3).

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