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Research Article

The Importance of Pressure Measurement in Orthognathic Surgery

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Abstract

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.

Pressure is a critical variable in many converting operations. Despite its importance, pressure often receives very scant attention. 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.

This pilot investigation was designed to apply several, newly developed and more sophisticated methods of measuring muscle structure and function to a situation where adaptation of muscle is pivotal to the success of a therapeutic approach.

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 (T2). In the proposed repeatability test, the occlusal pressure was measured for 30 consecutive patients twice by two different observers.

Keywords: *Orthognathic Surgery; Masseter Muscle; Pressure Measurement, Pressurex®*

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 undesirable [1].

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 dentitions [2].

Bite force has been used to evaluate masticatory function in patients before and after orthognathic surgery [3-7]. Usually, it has been measured with a custom bite force transducer [5,6,8].

In 1977, a pressure-sensitive sheet was developed for industrial examination by Fuji Photo Film Co (Tokyo, Japan). In 1978, it was reported that the pressure-sensitive sheet may be useful for measuring bite pressure and occlusal balance [9]. Recently, the pressure-sensitive sheet has been improved for dental use (Dental-Prescale, Fuji Photo Film Co). Bite force, occlusal contact area, and occlusal balance are measured and analysed using the pressure-sensitive sheet and its analysis apparatus (Occluzer, Fuji Photo Film Co) [10].

Pressure is a critical variable in many converting operations. It can be the single factor that determines the success or failure of a flexible packaging laminating adhesive, a heat seal adhesive, or numerous other products. Despite its importance, pressure often receives very scant attention. Converters usually set pressure to a certain predetermined level and vary it when problems occur in an attempt to provide a quick fix. This approach obviously has little scientific merit and is definitely a seat-of-the-pants approach that frequently does not provide optimum results.

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® (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.

Pressurex® system

Film description

The sensor consists of a polyester film contact sheet and a separate polyester film developer sheet. Adhered to the transfer sheet is a microencapsulated layer containing indicator material. Adjacent to this is a colour developing layer. Pressure applied to either side of the composite film causes the microencapsulated indicator to rupture and react with the colour developing layer. The resultant colour relates directly to the magnitude of pressure applied to the film. Higher pressure gives a more intense colour. This is very similar to use of pH indicating paper to determine the amount of acidity in an aqueous solution by the colour that develops when a drop of the solution contacts the pH indicating paper.

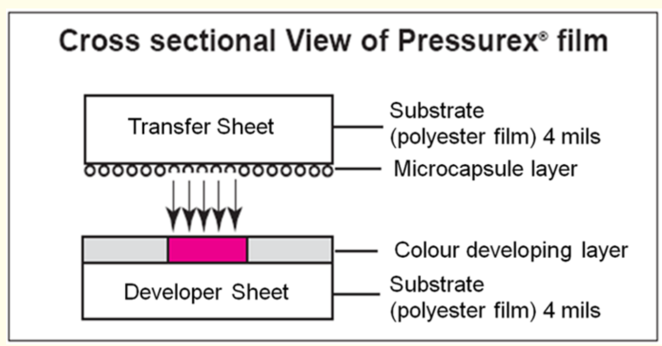

Figure 1: Cross sectional view of Pressurex® film.

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.

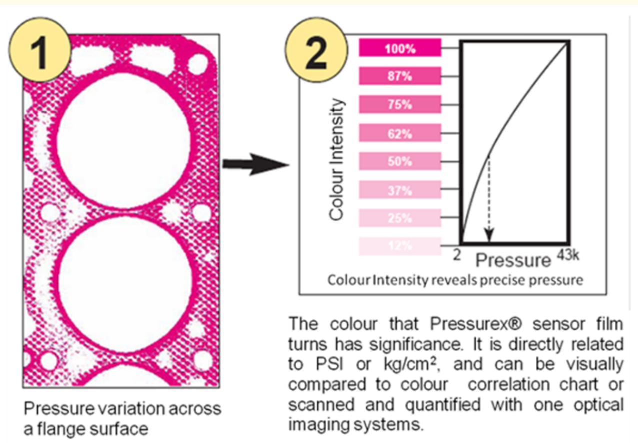

Figure 2: Colour intensity as a function of pressure.

Features

Offered in thicknesses from 4 mils to 20 mils, this system is flexible and allows natural occlusion and prevents mandibular displacement during clenching. The recording area cannot be easily damaged by artificial teeth materials or saliva as can articulating paper. The advantages of this system are as follows: (1) the thin material induces only a small change in the occlusal vertical dimension, making measurements at a position near the intercuspal position possible; (2) it is not necessary to prepare special measurement equipment; (3) many patients may be evaluated in short period of time; (4) record storage, even for an extended period, is simplified; and (5) it is easy to explain the treatment to patients by using images.

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.

Framework

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 visualized and the procedure was repeated after 10 minutes until the patient felt comfortable.

Figure 3: Clinical application of the metal framework containing the Pressurex® film.

Repeatability test

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 (T2). In the proposed repeatability test, the occlusal pressure was measured for 30 consecutive patients twice by two different observers. The results analysis were performed using the Magics 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,
- Q5: Left maxillary canine and left maxillary first pre-molar between 2nd and 3rd quadrants.

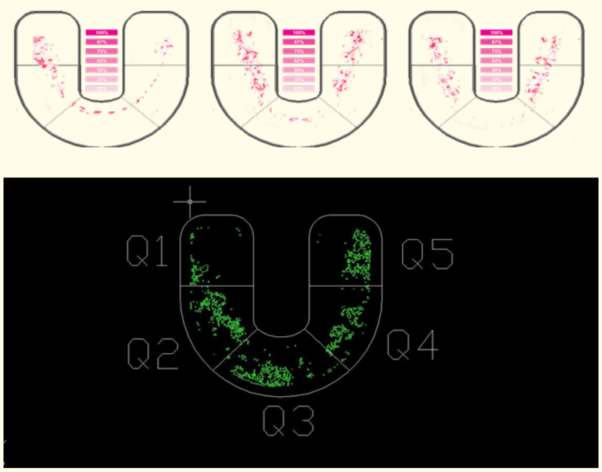

Figure 4: Biting area and pressure distribution in 5 areas.

Magics software

Materialize Magics is a versatile and intelligent data preparation software for (Additive Manufacturing), equipped with an intuitive and customizable user interface. This industry-leading software efficiently guides the user through every step of the 3D printing workflow. Materialize Magics is a modular solution with neutral technology. It allows to view slices, detect collisions, save platforms and generate useful reports.

A great design for 3D printing usually starts with a CAD project, a simulation result or digitized data as input. To take advantage of the possibilities offered by 3D printing, is important a flexible tool to make specific modifications or improvements to the design, usually at the mesh level.

With Magics, is possible natively import a large number of formats with 3D geometric information and also with the import of colors directly from the source file, which means that it is not necessary to create any intermediate files thus maintaining a better control of the original data.

Materials and Methods

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 (T2). In the proposed repeatability test, the occlusal pressure was measured for 30 consecutive patients twice by two different observers.

A combination of different parametric tests has been used to compare the different experimental variables. The experimental design devised for this study is depicted in figure 5, comprising a combination of different examiners, sensors and times of measurement.

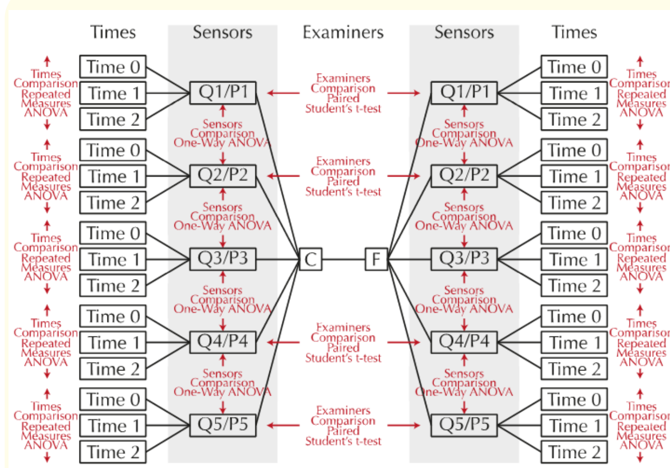

Figure 5: Experimental design used for the measurement of pressure sensor film. The study involved the contribution of two independent examiners (F and C), that measured the bite pressure (psi) in five different pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) at three different time moments (Time 0, Time 1 and Time 2).

Comparison A - Testing the differences between examiners (F versus C)

- Research question: Are there any differences in the mean bite pressure (psi) measured by Examiner F and Examiner C in the same experimental conditions?
- H0: There are no differences in the mean bite pressure (psi) measured by Examiner F and Examiner C in the same experimental conditions.
- H1: There are 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 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 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 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 pressure sensor film regions (Q1/P1 versus Q2/P2 versus Q3/P3 versus Q4/P4 versus Q5/P5)

- Research question: Are there any differences in the mean bite pressure (psi) measured by pressure sensor film regions Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5 in the same experimental conditions?
- H0: There are no 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 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 and Discussion

Table 1 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 (psi^2)
P1_F_T0	843,717	464,065	215356,281
P1_F_T1	878,345	357,570	127856,313
P1_F_T2	991,738	377,066	142178,838
P1_C_T0	1018,804	296,992	88204,323
P1_C_T1	928,723	416,187	173211,229
P1_C_T2	939,296	363,078	131825,476
P2_F_T0	885,162	404,791	163855,645
P2_F_T1	914,293	338,307	114451,662
P2_F_T2	996,813	323,275	104506,900
P2_C_T0	1023,033	279,275	77994,444
P2_C_T1	1038,681	276,343	76365,289
P2_C_T2	1042,910	176,101	31011,687
P3_F_T0	869,515	429,721	184660,248
P3_F_T1	793,339	449,685	202216,903
P3_F_T2	768,860	462,253	213677,913
P3_C_T0	938,450	372,302	138608,610
P3_C_T1	915,712	369,571	136582,765
P3_C_T2	806,077	420,978	177222,340
P4_F_T0	763,362	383,415	147007,393
P4_F_T1	791,646	296,446	87880,126
P4_F_T2	847,521	245,193	60119,824
P4_C_T0	906,307	228,538	52229,594
P4_C_T1	890,236	237,800	56548,717
P4_C_T2	889,813	237,800	58473,239
P5_F_T0	753,635	457,656	209448,945
P5_F_T1	835,630	327,232	107081,072
P5_F_T2	906,731	326,063	106317,248
P5_C_T0	923,225	306,928	94204,631
P5_C_T1	880,510	345,404	119304,143
P5_C_T2	848,368	302,521	91518,686

Table 1: Values of bite pressure (psi) measured by Pressurex® system at the different experimental conditions shown in figure 5.

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 pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) at the three different time moments (Time 0, Time 1 and Time 2).

Most of the results show no significant differences in the mean bite pressure (psi) measured by Examiner F and Examiner C, when the measurement is made in the same experimental conditions. The few differences observed ($p < 0,05$) where detected at Time 0 and/or Time 1 of measurement for the different pressure sensor film regions, probably due to small discrepancies in the experimental methodology that disappear by repetition of the protocol (at Time 2, e.g. no statistically significant differences were detected).

Overall, these results show 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 at-

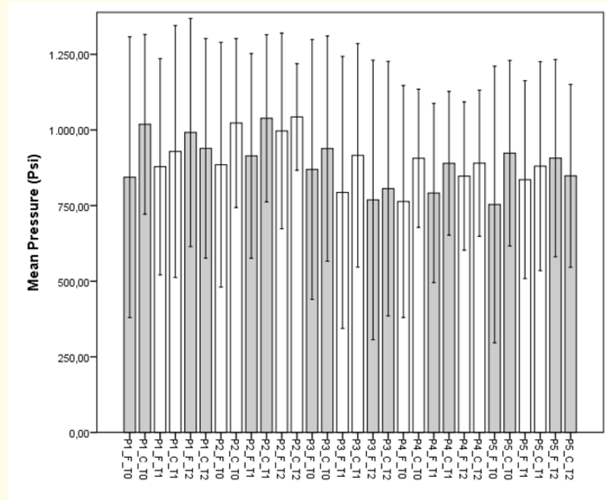

Figure 6: Mean bite pressure (psi) measured by Examiner F and Examiner C in five different pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) at three different time moments (Time 0, Time 1 and Time 2). Error bars represent standard deviation values.

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	-175,087	65,014	29	-2,693	0,012*
Examiner F versus Examiner C, P1, Time 1	-50,378	81,802	29	-0,616	0,543
Examiner F versus Examiner C, P1, Time 2	52,442	50,651	29	1,035	0,309
Examiner F versus Examiner C, P2, Time 0	-137,871	95,180	29	-1,449	0,158
Examiner F versus Examiner C, P2, Time 1	-124,388	51,539	29	-2,413	0,022*
Examiner F versus Examiner C, P2, Time 2	-46,097	60,452	29	-0,763	0,452
Examiner F versus Examiner C, P3, Time 0	-68,935	87,943	29	-0,784	0,439
Examiner F versus Examiner C, P3, Time 1	-122,373	52,226	29	-2,343	0,026*
Examiner F versus Examiner C, P3, Time 2	-37,216	69,925	29	-0,532	0,599
Examiner F versus Examiner C, P4, Time 0	-142,946	74,162	29	-1,927	0,064
Examiner F versus Examiner C, P4, Time 1	-98,167	57,347	29	-1,712	0,098
Examiner F versus Examiner C, P4, Time 2	-42,715	66,029	29	-0,647	0,523
Examiner F versus Examiner C, P5, Time 0	-169,590	80,479	29	-2,107	0,044*
Examiner F versus Examiner C, P5, Time 1	-44,880	63,775	29	-0,704	0,487
Examiner F versus Examiner C, P5, Time 2	58,363	54,388	29	1,073	0,292

Table 2: 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.

(*): The mean difference is significant at the 0,05 level.

tention 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 versus T1 versus 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 pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) and the different examiners F and C.

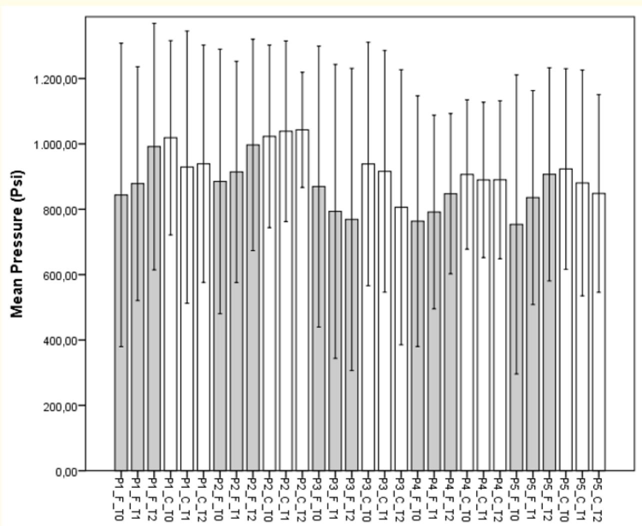

Figure 7: Mean bite pressure (psi) measured in three time moments (Time 0, Time 1 and Time 2) by Examiner F and Examiner C in five different pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5). Error bars represent standard deviation values.

There are no significant differences in the mean bite pressure (psi) measured at Time 0, Time 1 or Time 2, for the same Examiner (C or F) and the same pressure sensor film region (Q1/P1, Q2/P2, Q3/P3, Q4/P4 or Q5/P5) ($p > 0{,}05$). Almost all experiments reveal p-values above the cut-off value of 0,05 ($p > 0{,}05$), which means that H0 proposition is valid. The results obtained for Examiner C, pressure sensor film region Q3/P3, were not considered significant, as sphericity principle was not verified. Thus, it is concluded the mean bite pressure (psi) measured at different time frames is consistently the same, showing the high reproducibility of the measurements.

Times Comparison	Degrees of Freedom (df)	Test statistic (F)	P-value (Sig)
Time 0 vs Time 1 vs Time 2, Examiner F, P1	2, 58	1,926	0,155
Time 0 vs Time 1 vs Time 2, Examiner C, P1	2, 58	1,602	0,210
Time 0 vs Time 1 vs Time 2, Examiner F, P2	2, 58	0,908	0,409
Time 0 vs Time 1 vs Time 2, Examiner C, P2	2, 58	0,098	0,907
Time 0 vs Time 1 vs Time 2, Examiner F, P3	2, 58	0,702	0,500
Time 0 vs Time 1 vs Time 2, Examiner C, P3	2, 58	3,234 [(a)]	0,047 [(a)]
Time 0 vs Time 1 vs Time 2, Examiner F, P4	2, 58	0,704	0,499
Time 0 vs Time 1 vs Time 2, Examiner C, P4	2, 58	0,142	0,868
Time 0 vs Time 1 vs Time 2, Examiner F, P5	2, 58	1,928	0,155
Time 0 vs Time 1 vs Time 2, Examiner C, P5	2, 58	1,784	0,177

Table 3: 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.

a) Mauchly's Test of Sphericity ($p < 0{,}05$) reveals violation of sphericity principle, indicating distortion in the calculation of variance, F-ratio and p-value obtained in these results for the Repeated Measures ANOVA.

Comparison C - Testing the differences between pressure sensor film regions (Q1/P1 versus Q2/P2 versus Q3/P3 versus Q4/P4 versus Q5/P5)

The statistical comparison between the five pressure sensor film regions sensors (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).

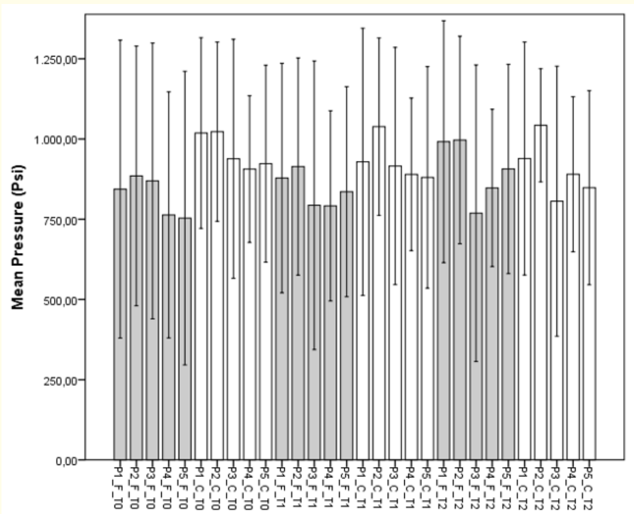

Figure 8: Mean bite pressure (psi) measured in five pressure sensor film regions sensors (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) by Examiner F and Examiner C at three different time moments (Time 0, Time 1 and Time 3). Error bars represent standard deviation values.

Most of the results show no significant differences in the mean bite pressure (psi) measured by the different pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5), when the measurement is made in the same experimental conditions. All experiments reveal p-values above the cut-off value of 0,05 ($p > 0,05$), with exception of the pressure sensor film regions at Time 2 for Examiner C ($p = 0,041$).

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 pressure sensor film regions at Time 2 for Examiner C, in order to detect the specific pairs of pressure sensor film regions where statistically significant differences were identified (Table 5).

Post-Hoc Gabriel Test has determined that the differences observed between pressure sensor film regions at Time 2 for Examiner C (One-Way ANOVA, Table 4) are located in the pair of sensors Q2/P2 and Q3/P3 ($p = 0,038$). These differences are not observed

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	444755,025	4	111188,756	0,604	0,660
	Within Groups	26689526,855	145	184065,702		
	Total	27134281,880	149	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner F, Time 1	Between Groups	344673,468	4	86168,367	0,674	0,611
	Within Groups	18545096,189	145	127897,215		
	Total	18889769,658	149	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner F, Time 2	Between Groups	1132748,174	4	283187,043	2,259	0,066
	Within Groups	18177220,971	145	125360,145		
	Total	19309969,145	149	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner C, Time 0	Between Groups	363347,870	4	90836,967	1,007	0,406
	Within Groups	13086006,451	145	90248,320		
	Total	13449354,321	149	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner C, Time 1	Between Groups	482377,818	4	120594,455	1,073	0,372
	Within Groups	16298352,160	145	112402,429		
	Total	16780729,979	149	-		
P1 vs P2 vs P3 vs P4 vs P5, Examiner C, Time 2	Between Groups	1002170,542	4	250542,635	2,556	0,041*
	Within Groups	14211491,376	145	98010,285		
	Total	15213661,918	149	-		

Table 4: Statistical parameters obtained in the One-Way ANOVA for the comparison of pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) when measuring the mean bite pressure (psi) in different experimental conditions.

(*): The mean difference is significant at the 0,05 level.

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
F_T0	Q1/P1	Q2/P2	-41,445	110,775	1,000	C_T0	Q1/P1	Q2/P2	-4,229	77,566	1,000
		Q3/P3	-25,798	110,775	1,000			Q3/P3	80,354	77,566	0,970
		Q4/P4	80,355	110,775	0,998			Q4/P4	112,497	77,566	0,794
		Q5/P5	90,082	110,775	0,995			Q5/P5	95,580	77,566	0,912
	Q2/P2	Q1/P1	41,445	110,775	1,000		Q2/P2	Q1/P1	4,229	77,566	1,000
		Q3/P3	15,648	110,775	1,000			Q3/P3	84,583	77,566	0,958
		Q4/P4	121,801	110,775	0,956			Q4/P4	116,726	77,566	0,757
		Q5/P5	131,527	110,775	0,929			Q5/P5	99,809	77,566	0,888
	Q3/P3	Q1/P1	25,798	110,775	1,000		Q3/P3	Q1/P1	-80,354	77,566	0,970
		Q2/P2	-15,648	110,775	1,000			Q2/P2	-84,583	77,566	0,958
		Q4/P4	106,153	110,775	0,983			Q4/P4	32,143	77,566	1,000
		Q5/P5	115,880	110,775	0,968			Q5/P5	15,225	77,566	1,000
	Q4/P4	Q1/P1	-80,355	110,775	0,998		Q4/P4	Q1/P1	-112,497	77,566	0,794
		Q2/P2	-121,801	110,775	0,956			Q2/P2	-116,726	77,566	0,757
		Q3/P3	-106,153	110,775	0,983			Q3/P3	-32,143	77,566	1,000
		Q5/P5	9,727	110,775	1,000			Q5/P5	-16,917	77,566	1,000
	Q5/P5	Q1/P1	-90,082	110,775	0,995		Q5/P5	Q1/P1	-95,580	77,566	0,912
		Q2/P2	-131,527	110,775	0,929			Q2/P2	-99,809	77,566	0,888
		Q3/P3	-115,880	110,775	0,968			Q3/P3	-15,225	77,566	1,000
		Q4/P4	-9,727	110,775	1,000			Q4/P4	16,917	77,566	1,000
F_T1	Q1/P1	Q2/P2	-35,948	92,339	1,000	C_T1	Q1/P1	Q2/P2	-109,958	86,565	0,895
		Q3/P3	85,006	92,339	0,987			Q3/P3	13,011	86,565	1,000
		Q4/P4	86,699	92,339	0,985			Q4/P4	38,910	86,565	1,000
		Q5/P5	42,715	92,339	1,000			Q5/P5	48,213	86,565	1,000
	Q2/P2	Q1/P1	35,948	92,339	1,000		Q2/P2	Q1/P1	109,958	86,565	0,895
		Q3/P3	120,954	92,339	0,876			Q3/P3	122,969	86,565	0,813
		Q4/P4	122,647	92,339	0,867			Q4/P4	148,868	86,565	0,593
		Q5/P5	78,663	92,339	0,993			Q5/P5	158,171	86,565	0,508
	Q3/P3	Q1/P1	-85,006	92,339	0,987		Q3/P3	Q1/P1	-13,011	86,565	1,000
		Q2/P2	-120,954	92,339	0,876			Q2/P2	-122,969	86,565	0,813
		Q4/P4	1,693	92,339	1,000			Q4/P4	25,899	86,565	1,000
		Q5/P5	-42,291	92,339	1,000			Q5/P5	35,202	86,565	1,000
	Q4/P4	Q1/P1	-86,699	92,339	0,985		Q4/P4	Q1/P1	-38,910	86,565	1,000
		Q2/P2	-122,647	92,339	0,867			Q2/P2	-148,868	86,565	0,593
		Q3/P3	-1,693	92,339	1,000			Q3/P3	-25,899	86,565	1,000
		Q5/P5	-43,984	92,339	1,000			Q5/P5	9,303	86,565	1,000
	Q5/P5	Q1/P1	-42,715	92,339	1,000		Q5/P5	Q1/P1	-48,213	86,565	1,000
		Q2/P2	-78,663	92,339	0,993			Q2/P2	-158,171	86,565	0,508
		Q3/P3	42,291	92,339	1,000			Q3/P3	-35,202	86,565	1,000
		Q4/P4	43,984	92,339	1,000			Q4/P4	-9,303	86,565	1,000

F_T2	Q1/P1	Q2/P2	-5,075	91,419	1,000	C_T2	Q1/P1	Q2/P2	-103,614	80,833	0,890
		Q3/P3	222,878	91,419	0,147			Q3/P3	133,219	80,833	0,649
		Q4/P4	144,217	91,419	0,704			Q4/P4	49,060	80,833	1,000
		Q5/P5	85,007	91,419	0,986			Q5/P5	90,928	80,833	0,949
	Q2/P2	Q1/P1	5,075	91,419	1,000		Q2/P2	Q1/P1	103,614	80,833	0,890
		Q3/P3	227,952	91,419	0,128			Q3/P3	236,83333*	80,833	0,038*
		Q4/P4	149,291	91,419	0,661			Q4/P4	152,674	80,833	0,460
		Q5/P5	90,082	91,419	0,979			Q5/P5	194,542	80,833	0,159
	Q3/P3	Q1/P1	-222,878	91,419	0,147		Q3/P3	Q1/P1	-133,219	80,833	0,649
		Q2/P2	-227,952	91,419	0,128			Q2/P2	-236,83333*	80,833	0,038*
		Q4/P4	-78,661	91,419	0,992			Q4/P4	-84,160	80,833	0,969
		Q5/P5	-137,870	91,419	0,755			Q5/P5	-42,291	80,833	1,000
	Q4/P4	Q1/P1	-144,217	91,419	0,704		Q4/P4	Q1/P1	-49,060	80,833	1,000
		Q2/P2	-149,291	91,419	0,661			Q2/P2	-152,674	80,833	0,460
		Q3/P3	78,661	91,419	0,992			Q3/P3	84,160	80,833	0,969
		Q5/P5	-59,209	91,419	0,999			Q5/P5	41,869	80,833	1,000
	Q5/P5	Q1/P1	-85,007	91,419	0,986		Q5/P5	Q1/P1	-90,928	80,833	0,949
		Q2/P2	-90,082	91,419	0,979			Q2/P2	-194,542	80,833	0,159
		Q3/P3	137,870	91,419	0,755			Q3/P3	42,291	80,833	1,000
		Q4/P4	59,209	91,419	0,999			Q4/P4	-41,869	80,833	1,000

Table 5: Statistical parameters obtained in the Post-Hoc Gabriel test for the comparison of pressure sensor film regions (Q1/P1, Q2/P2, Q3/P3, Q4/P4 and Q5/P5) when measuring the mean bite pressure (psi) in different experimental conditions.

(*): The mean difference is significant at the 0,05 level.

in the same conditions for Examiner F, which supports the absence of significant variations in the mean bite pressure (Psi) detected by the five pressure sensor film regions used in the experimental design.

Conclusion

The versatility of PressureX® system as a pressure indicating sensor film was tested to evaluate the bite pressure distribution of a number of patients following orthodontic/orthognathic surgery. For this purpose, a metal framework in a horseshoe-shaped form was developed to accommodate this sensor film for orthodontic and a measurement procedure was developed to attain optimal measurement repeatability.

Results have shown that PressureX® system can be successfully used for qualitative evaluation of bite pattern, although it presents some limitations in terms of quantitative assessment of bite pressure (psi), such as examiners and repeatability variations.

Although it is still not clear the origin of these experimental variations, two different strategies will be explored in the future to attain higher levels of reproducibility: 1) development of an optimized measurement procedure and; 2) testing of a new image processing software such as the Java-based software ImageJ.

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