Original Article

Occlusal Morphology 1 Year after Orthodontic and Surgical-Orthodontic Therapy

A Quantitative Analysis of Clinically Successful Patients

Claudia Dellavia[a]; Luis Tomas Huanca Ghislanzoni[b]; Redento Peretta[c]

ABSTRACT

Objective: To evaluate morphologic characteristics of occlusion (contact points, contact areas, and frequency of contact) in clinically successful patients 1 year after orthodontic and surgical-orthodontic therapy followed by passive retention.

Materials and Methods: Twenty-two orthodontic and 18 surgical-orthodontic patients were analyzed. All patients were treated with standard edgewise technique by the same orthodontist. Contact points and areas were evaluated using a new method of digital image analysis of occlusal impressions. Polivinylsyloxan impressions were taken, scanned, and turned into gray-scale images. The physic relationship of light absorbance through the polivinylsyloxan for known thickness was calculated to determine contact areas (less than 50 μm of thickness) and near contact areas (less than 350 μm of thickness).

Results: The contact area was significantly larger in the orthodontic than in the surgical-orthodontic patients (Student's *t*-test, $P < .05$). The surgical-orthodontic group had significantly fewer contact points than the orthodontic group only at 150 μm of thickness. In both groups of patients, the first molar had the largest contact surface. Occlusal support was distributed mainly in the posterior regions with an important role involving the first molars.

Conclusion: Surgical-orthodontic patients appear to have smaller contact surfaces and fewer contact points than orthodontic patients do. However, there were no differences in the number of teeth in contact with opposing teeth.

KEY WORDS: Occlusion; Retention; Orthognathic surgery

INTRODUCTION

Clinical success after orthognathic therapy can be defined as a combination of six factors: (1) patient (and patient's family) satisfaction, (2) correct occlusal relationship (one tooth against two), (3) stability 1 year after treatment, (4) incisal/canine guide with posterior disclusion in protrusive and lateral movements, (5) patient comfort when chewing, and (6) no pain in the temporomandibular joint (TMJ).[1–3]

[a] Research Assistant, Department of Human Morphology, University of Milan, Milan, Italy.

[b] Postgraduate Student (DDS), Department of Human Morphology, University of Milan, Milan, Italy.

[c] Postgraduate student (MD, PhD), Department of Human Morphology, University of Milan, Milan, Italy.

Corresponding author: Dr Claudia Dellavia, Department of Human Morphology, University of Milan, Via Mangiagalli 31, Milano, Italy 20133 (e-mail: claudia.dellavia@unimi.it)

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These objectives can be assessed using Andrews's[4] six keys to define the best occlusion when finishing a case. It is clinically accepted that occlusion control is transferred from appliances to a patient's neuromuscular system at the end of treatment. Unfortunately, the modality of occlusal assessment is still unknown. It can be supposed that there is a good integration between new occlusal morphology and muscular function when occlusion shows stability along time and the follow-up is negative for TMJ pain. It is of clinical interest to define anatomic parameters to assess the evolution of each case during the period of occlusal recovery (1 to 3 years after treatment).

Sullivan et al[5] found fewer contact points in postorthodontic patients than in control subjects, with the number of contacts increasing with time. Further along in retention, occlusion is a dynamic condition influenced by the natural tendency to relapse, occlusal forces, the neuromuscular system, and the retention appliances themselves. Occlusal recovery involves many factors, and a variation in contact points is related to overbite/overjet modifications.[6] In conventional orthodontic treatment, there is a 14% augment in the number of contact points at 3 months,[7] which becomes 56% at 1 year.[8]

Several methods have been proposed to measure contact areas. Unfortunately, most of these systems are operator dependent.[9] The polyvinyl-siloxane impression method is virtually operator independent with great repeatability.[10] The material is fluid before setting, thus having nil resistance to mandibular closure force without modifying the proprioceptive sensation during clenching. Contact points and surfaces have been studied by digital image analysis of silicon impression thickness in control subjects and compared to subjects with malocclusion[11] and to postorthodontic patients.[12] In addition, the interpretation of digital data obtained with the scanning of the impressions, where described, appears imprecise.[11]

To date, few data about occlusal morphology in post–surgical-orthodontic patients are available.[13]

The objective of the current study is to describe the characteristics of occlusion in surgical-orthodontic patients compared to conventionally treated orthodontic patients 1 year after the end of the orthodontic therapy, applying a new method of computing areas and points of contact and near contact from polyvinyl-siloxane occlusal impressions.

MATERIALS AND METHODS

Forty patients aged 14 to 32 years were analyzed: 22 patients (6 men, 16 women; mean age = 20.0 years, SD = 6.3, range = 14–28) were treated with orthodontic therapy (ORTHOs) and 18 patients (6 men, 12 women; mean age = 24.8 years, SD = 4.4, range = 18–32) were treated with surgical and orthodontic therapy (SURGs).

Before the therapy, the orthodontic group was composed of 4 skeletal Class I malocclusion patients ($0° < ANB < 4°$), 15 patients with a Class II tendency, and 3 patients with a Class III tendency. The surgical group was composed of 3 patients with a Class II tendency and 15 patients with a skeletal Class III malocclusion. In both groups, most of the subjects had a normal vertical dimension (facial index = 60%–70%); only a few cases of open and deep bite were observed.

Surgical patients were treated with combined maxillary Le Fort I and sagittal mandibular osteotomies. All subjects were treated with a standard edgewise technique by the same orthodontist. The orthodontic therapy ended about 6 months after surgery.

After the completion of the orthodontic treatment, the vertical dimension showed only a minimal variation, while all patients finished with a skeletal Class I occlusion (mean ANB of ORTHOs = $2.2° \pm 1.6°$; SURGs = $2.2° \pm 1.3°$), except for four surgical patients with Class II tendencies.

After treatment, the patients' occlusion was stabilized with a Begg plaque in the upper arch and a spring retainer in the lower arch.

At the first-year recall, patients completed a self-administered questionnaire specifically designed to measure their satisfaction (esthetic appearance, comfort when chewing, absence of pain in the TMJ). All patients were satisfied. In addition, the orthodontist assessed a correct occlusal relationship (one tooth against two), incisal/canine guide with back disclusion in protrusive and lateral movements, and stability 1 year after treatment.

The current measurements were performed at the first year after the beginning of retention (12 months after orthodontic treatment completion for both groups, 18 months after surgery for the surgical patients).

All subjects gave their informed consent to the experiment. All procedures were noninvasive and performed with minimal discomfort to the subjects. All occlusal impressions were performed by a single operator. The study protocol was approved by the local ethics committee.

Estimation of Occlusal Contact Areas and Points

Occlufast Rock (Zhermack Inc, Trieste, Italy) silicone-based registrations of occlusion were obtained in maximum intercuspation. This polyvinyl-siloxane was chosen because of the ease of dispensing and application, good viscosity, fast setting time (1 minute), detail of impression, and hardness and rigidity once set. The impression material was injected on the occlusal plate of all the teeth of the lower arch with a disposable syringe. Each subject was seated upright in a dental chair, maintaining the natural head position. Patients were asked to bite down firmly into maximum intercuspation for 20 seconds and to keep this position with a light force until the material had set.

An image of each occlusal registration was obtained with a Hewlett Packard ScanJet 6100C/T scanner (Palo Alto, Calif). A standard record at known thickness was used to check the same light power for each scanning. The software program Adobe Photoshop was used to convert the image into a luminance (grayscale) image and to manually insulate the platform area of each tooth (Figure 1).

Since the opacity of the material increases proportionally to thickness, calibration step wedges of polyvinyl-siloxane of known thickness were used to establish the relationship between each level of the 256 gray scale and the thickness of the occlusal registration (Table 1; Figure 2). Thickness was measured us-

Figure 1. Scanned image of the occlusal registration (mandibular surface facing downward) in one orthodontic patient. On the left side is an example of manual insulation of each single tooth.

ing a diabase control plane with comparator. The mean error was ±20 μm. The calibration step wedges were scanned and analyzed with Image Pro Plus software (Media Cybernetics Inc, Silver Spring, Md). A gray-scale value according to the pixel density was obtained (ie, the thickness of the sample). Using a physical theoretical approach to the phenomenon of light absorbance through a material, we defined an equation that fit with our data as

$$y = 455{,}614 \cdot e^{(-0{,}000993x) \cdot x^{-0{,}19099}}$$

where x is the value of thickness in micrometers and y the luminosity in gray-scale values.

According to previous studies with silicone impressions,[10,14] actual contacts were defined as areas of contact with a thickness at or below 50 μm, and near contacts were defined as those with a thickness at or below 350 μm. Contact areas and points were considered at 50, 150, 250, and 350 μm after calculating the gray-scale equivalent of the threshold thickness.

In addition, the frequency of contact was computed evaluating the presence of at least one contact point on each tooth.

An asymmetry index for contact areas and points was calculated according to the following formula:

Table 1. Thickness and Luminosity With Error Measures (Range and SD) for Each Calibration Step Wedge

Step Wedge, n	Thickness, μm	Range	Luminosity, GS[a]	SD
1	50	20–70	208.2	11.9
2	90	70–110	174.8	13.6
3	120	100–140	156.7	11.7
4	170	160–200	141.2	9.3
5	250	210–300	125.2	4.3
6	270	240–300	120.5	9.0
7	320	290–360	110.3	3.9
8	600	570–630	73.0	5.9

[a] GS indicates gray-scale value.

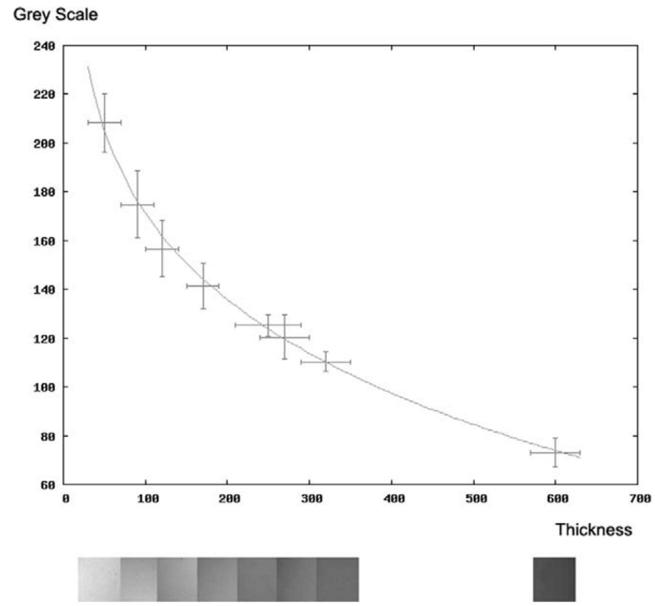

Figure 2. Relation between thickness in μm (x) and luminosity in gray scale (y).

$$\text{Asymmetry Index} = \frac{\text{right side} - \text{left side}}{\text{right side} + \text{left side}} \times 100$$

The absolute values of the asymmetry index were also used to avoid right- or left-side prevalence. For each patient, the relative weight of every tooth/group of teeth contact area was balanced on the total area. The same procedure was performed for the number of contact points.

The repeatability of the procedure (impression, scanning, and manual insulation of single teeth) was tested, repeating the examination 4 times in 6 control subjects. A good repeatability was assessed, as the mean coefficient of variation was 2.3% (range, 0.6%–5.1%) for contact areas and 4.8% for contact points, (range, 1.2%–8.4%).

Statistical Analyses

For each subject, the area and number of contacts for each tooth were computed. The skewness and kurtosis showed that the total area and the number of contacts were normally distributed within each group. Descriptive statistics (mean, standard deviation, and coefficient of variation) were calculated for each variable (age, contact area, and points).

The mean values of each variable were compared in the two groups of patients using a Student's *t*-test for independent samples. Comparisons between groups were computed by a two-way factorial analysis of variance (ANOVA) test to evaluate the effect of therapy (factor 1) and the location of the teeth in the arch (eg, anterior/posterior; factor 2). The interaction be-

Table 2. Contact Area and Points in the Orthodontic and Surgical-Orthodontic Patients

Measurement	Orthodontic (n = 22)			Surgical-Orthodontic (n = 18)			Student's *t*-Test
	x̄	SD	CV, %	x̄	SD	CV, %	
Area, mm²							
<50 μm	15.3	9.2	60	6.9	3.1	49	***
<150 μm	42.6	19.8	45	28.3	13.7	47	*
<250 μm	74.7	28.1	38	54.2	24.6	45	*
<350 μm	99.4	33.4	33	75.0	31.9	42	*
Points (n)							
<50 μm	21.3	9.1	43	17.2	6.3	36	ns[a]
<150 μm	26.8	6.0	23	22.2	6.3	27	*
<250 μm	27.3	5.1	19	24.6	6.0	25	ns
<350 μm	26.0	4.3	16	24.3	5.7	21	ns

[a] ns indicates not significant.
* $P < .05$; ** $P < .01$; *** $P < .001$.

tween the two factors was also computed. A χ^2 test was used to compare the gender distribution and the frequency of contact of each tooth and group of teeth between the two groups of patients.

A correlation coefficient was computed to assess the influence of age on contact areas and points. For all analyses, the level of significance was set at 5% ($P < .05$).

RESULTS

Significant age differences were found between the two groups of patients. The ORTHOs were younger than the SURGs (Student's *t*-test, $P < .05$). No difference in gender distribution was found between the two groups (χ^2 test). Within each group, no significant effect of age was found on contact areas and points (correlation coefficient, $P > .05$).

Table 2 reports the mean area and points of contact (<50 μm) and near contact at ≤350 μm and at intermediate thickness. There was a great intragroup variability, with the coefficient of variation ranging from 33% to 60% for the areas and 16% to 43% for the number of points. The ORTHOs' contact area was significantly larger than the SURGs' area at all levels (Student's *t*-test, $P < .05$; Figure 3). The contact points were significantly different only at 150-μm thickness ($P < .05$).

The mean values of area and contact points separately for each tooth are reported in Table 3. The mandibular first molar had the largest contact area in both groups and the highest number of contact points in the ORTHOs.

Differences between the contact area and points on the right and left sides were not statistically significant for the overall patients nor for the two groups (Student's *t*-test). For the overall patients, the mean index of asymmetry was −3% for areas (SD = 29%) and −1% for points (SD = 22%). The mean absolute values of the index were 24% for areas (SD = 17%) and 16% for points (SD = 15%).

In the observed patients, 390 of the 556 (70%) analyzed mandibular teeth (two patients had their first premolars extracted) were in contact with their maxillary opponents: a mean of 9.8 mandibular teeth were in contact with their opponents (SD = 2.6). There were no differences between the two groups. Of the 390 teeth in contact, 196 contacts occurred on the right side and 194 on the left side. The anterior teeth (incisors and canines) were in contact in 45% of the ORTHOs (60 of 132) and in 52% of the SURGs (56 of 114). The posterior teeth (premolars and molars) were in contact in 88% of the ORTHOs (152 of 172) and in 85% of the SURGs (122 of 152). On average, the teeth with the highest frequency of contact were the first molar (95% ORTHOs; 100% SURGs) and the second molar (98% ORTHOs; 89% SURGs). There were no significant differences between the two groups in the frequency of contact of single (Table 3) or grouped (anterior, posterior) teeth (χ^2 test).

The contact area and points' relative weight per group of teeth in the ORTHOs and in the SURGs are listed in Table 4. Between the two groups of patients, no differences were found in the distribution of contact

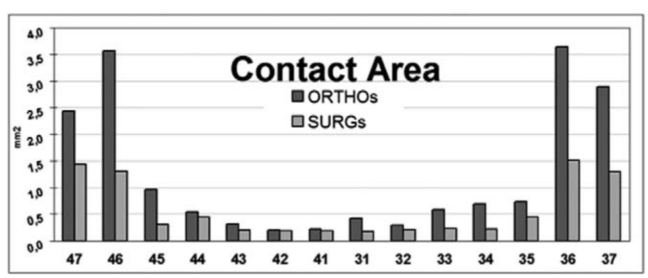

Figure 3. Mean contact area of each single tooth in orthodontic (ORTHOs) and surgical-orthodontic patients (SURGs). On the *x*-axis are the mandibular teeth; on the *y*-axis is the contact area (thickness ≤50 μm) in mm².

Table 3. Mean Area, Points, and Frequency of Contact for Each Mandibular Tooth in the Two Groups of Patients

Tooth	Orthodontic (n = 22)			Surgical-Orthodontic (n = 18)		
	Area, mm^2	Points	Frequency, %[a]	Area, mm^2	Points	Frequency, %[a]
Central incisor	0.3	1.0	25	0.2	1.1	44
Lateral incisor	0.2	1.2	43	0.2	1.5	39
Canine	0.4	1.3	68	0.2	1.0	72
First premolar	0.6	1.3	75	0.3	1.2	72
Second premolar	0.8	2.1	84	0.4	1.5	78
First molar	3.6	3.8	95	1.4	2.5	100
Second molar	2.7	2.8	98	1.4	2.7	89

[a] Frequency, % indicates the frequency of presence in contact.

area and number of contact points' relative weights; in addition, the interaction between the two factors was not significant (ANOVA two-way test). No effect of the location of the teeth in the arch (anterior and posterior teeth) was found, and the interaction of the location factor with the therapy factor was not significant.

DISCUSSION

The photo-occlusion technique is operator independent. It is a computerized, semiautomatic image analysis system that recognizes the occlusal contacts and near contacts according to a threshold thickness/luminosity previously identified. In the present investigation, the silicon was preferred to other materials since it appeared to be the most precise, repeatable, and operator-independent material to examine occlusal morphology.[9,11] A pilot study was conducted so that the operator could become familiar with the experimental procedure. The current protocol was similar to the one defined by Owens et al,[11] but the calibration curve describing the intensity of light expressed in gray scale was more accurate for thicknesses greater than 50 μm. The present curve represents an optimal approximation of light behavior through the impression material for values of thickness (larger than 50 μm) concerning contact and near-contact points. These concerns minimized bias.

Table 4. Contact Area and Points' Relative Weight (in Percentages) per Group of Teeth (Balanced on Total Area/Points) in the Two Groups of Patients

Teeth Group	Orthodontic (n = 22)		Surgical-Orthodontic (n = 18)	
	Area %	Points %	Area %	Points %
Incisors	6	16	9	22
Canines	5	9	5	9
Premolars	17	25	17	23
Molars	72	50	68	46
Anteriors[a]	12	25	15	32
Posteriors[b]	88	75	85	68

[a] Incisors and canines.
[b] Premolars and molars.

In the present study, the orthodontic patients were significantly younger than the surgical ones. All of the ORTHOs underwent therapy after the pubertal growth peak, in the last phase of growth, while the SURGs can be definitely considered an adult sample. The age difference is due to the necessity of growth ending before performing surgical treatment. The influence of age cannot be excluded in occlusal recovery independent from the therapy. Most investigations refer to adolescent subjects, which allows us to compare our orthodontic group with results of previous studies.[12,15] Nevertheless, contact and near-contact surfaces at 50 and 350 μm were independent from gender and age in accordance with Gurdsapsri et al.[10]

Previous studies[16,17] found 7 to 12 contact points for hemimandibles in healthy subjects. Similarly, 9.7 $\pm$ 4.1 contact points for hemimandibles were found in the present work. Dincer et al[12] compared 20 untreated subjects with 20 orthodontic patients after 9 months of retention. They found no differences in the number of contact points between patients and controls. The current data in the orthodontic group were comparable with these findings[12] and led us to investigate weather the occlusion in surgical-orthodontic patients at the end of treatment is comparable with occlusion of pure orthodontic patients.

The mean contact area appears to be related to the therapy. The ORTHOs' contact area and near-contact area are significantly larger than the SURGs' values. A possible explanation of these results could be the change of chewing habits of all patients undergoing surgical treatment. After surgery, patients report a certain difficulty when grinding food and a discomfort when biting hard foods, such as bread and carrots. This sensation improves with time, until disappearing 1 to 2 years after surgery. Masticatory efficiency measured with standard sieve techniques in surgical patients was found to be lower than in control subjects.[18]

The postsurgical functional situation was generally better than the presurgical one. The masticatory cycles were less variable, showing a higher stability of occlusion.[19,20] Other investigations found a relation between chewing efficiency/number of teeth in contact and area of near contact.[21] The smaller area and the fewer contact points observed in the SURGs than in the ORTHOs could be explained by the lower dynamic stimulus to mastication of surgical patients during the occlusal recovery period. Since considerable change in bite force, which is not primarily related to jaw movement, occurs after orthognathic surgery,[22] these changes may explain a significant proportion of the differences between the groups in the number and size of contact areas. This factor in conjunction with the inherent compressibility of the periodontal ligament may explain the differences observed when the teeth were held in occlusion. Furthermore, the lack of any way of standardizing the occlusal force may also have influenced the findings.

Nevertheless, an increased number of contacts in post–surgical-orthodontic patients 6 months after surgery was reported by Athanasiou.[13] In the current work, patients were evaluated 18 months after surgery, and at this time, their recovery period may be not concluded yet.

The absolute values of the asymmetry index found for the area and the number of contact points indicate a certain degree of individual asymmetry, in accordance with the work of McDevitt and Warreth.[6]

The absence of contact between the upper and lower anterior teeth occurred in 53% of the analyzed patients. Similar findings in young control subjects were reported by McNamara and Henry (40%).[15] A 15% lack of contact was observed among the posterior teeth of the analyzed subjects. Possible explanations could be the straightening of the curve of Spee, the augment of the upper curve, and the overtreatment of overbite/overjet.

The higher frequency of contact of the central incisor in SURGs than in ORTHOs may be accounted for by the total horizontal anterior relapse and postoperative counterclockwise rotation of the mandible observed in surgical Class III patients (most SURGs) after bilateral sagittal split osteotomy.[23]

The number of contacts on first molars in the ORTHOs is comparable to the findings of Dincer et al[12] in normal subjects. Molars are the teeth more frequently in contact with their opponents, which underlines their role in keeping occlusal stability. Further studies in larger samples are needed to define the morphologic occlusal changes in orthodontic and surgical-orthodontic patients after 1 year of retention.

Although there were differences between the groups in terms of the size and number of contacts, there were no differences in the number of teeth in contact with opposing teeth. Furthermore, there were no differences in the frequency of contacting teeth when this was further analyzed by grouped teeth (anterior or posterior). The way the orthodontists finish cases, in accordance to the literature,[2–4] is probably what determines the number of teeth in contact with their opponents. In contrast, the size and number of contacts could be related to the neuromuscular system recovery peculiar of each patient.

CONCLUSIONS

- The analyzed surgical-orthodontic patients had smaller contact surfaces and fewer contact points than orthodontic patients did.
- There were no differences in the number of teeth in contact with opposing teeth.

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