Biomechanics of Pivoting Appliances

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The effects of fulcrum-type splints on the temporomandibular joints are unclear. An analysis of bilateral temporomandibular joint linear tomograms of 20 volunteers was made. This study was carried out to evaluate and quantify the condylar distraction caused by the use of interocclusal splints with pivots located simultaneously on second molars. Statistical results showed an average condylar lowering of 1.3 mm in 87.5% of the subjects (P < .05) while clenching with lips closed and wearing this splint. A real bilateral condylar distraction was shown in 30% of the subjects, 35% showed both condyles in a protruded position, and 35% of the subjects showed a combined situation.

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The study of temporomandibular joint (TMJ) loading has been of great interest since the beginning of this century, because it is known that the compressive overloading can cause intra-articular derangement[1,2] and functional remodeling[3,4] of the TMJ structures. The pivoting appliances were first mentioned by Sears[5] in 1956. Lous[6] subsequently presented a study with these splints in which he used a facial strap to induce anterior forces to the mandible and showed very successful clinical results. There are many studies in the current literature that analyze TMJ loads by using different methods. Most conclude that the pivoting splint cannot distract the condyles.[7,8]

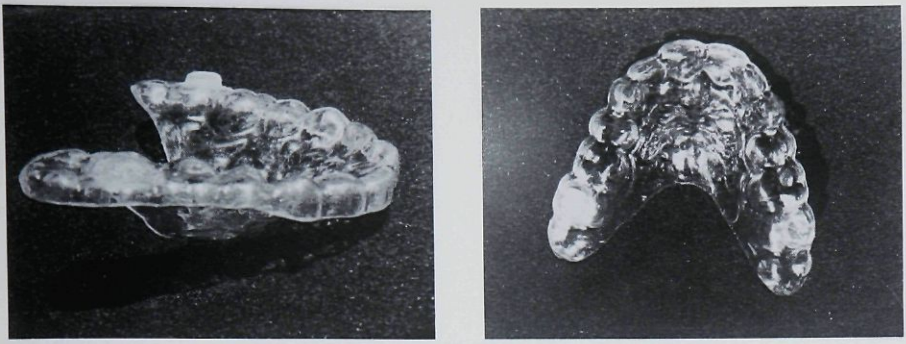
It has also been demonstrated that the major momentum of force is generated when the subject bites on the first molars, and that the mandible acts as a class III lever with anterior forces applied to the second molar.[9,10]

The purpose of this study was to observe and quantify, by means of TMJ linear tomograms, the amount of distraction caused by the use of an interocclusal splint with pivots located on the second molar areas.

Materials and Methods

The sample (n = 20, average age 24.3 years) was taken from volunteer students of the School of Dentistry of the Javeriana University in Bogota, Colombia. All subjects exhibited minimal tooth wear, normal tooth mobility, and good periodontal health. A criterion for inclusion in the study was the presence of maxillary and mandibular second molars.

An upper cast was obtained from each subject, and a splint was fabricated using acetate sheets of 0.6 gauge (1.0 mm) in a vacuum system (Sta Vac, National Keystone, Philadelphia, PA); the splint was tried in the patient's mouth to assure adequate fit. Stops were made with transparent acrylic resin (Quimident, Premon Industria Quimica, Barranquilla, Colombia) and placed on the maxillary



Figs 1a and 1b Interocclusal splint with the bilateral acrylic pivots located on the maxillary second molar areas.

second molar areas, which had a circular flat surface 5.0 mm in diameter with a height of 1.5 mm. The appliance was placed and the stops were adjusted until the patient felt uniform pressure on both contacts (Figs 1a and 1b).

The tomograms were taken according to the axially corrected tomogram technique described by Pullinger,[11] using a Quint Sectograph x-ray unit (Denar, Anaheim, CA). This unit has a tomographic arc of 60 degrees, 76 to 78 KV(p), and 50 mAs with a 3-second exposure. The x-ray was collimated to 6 × 7 cm.

The tomographic cuts for the first x-ray view were made with the patient instructed to clench the teeth and keep the lips closed. For the second one, the patient was instructed to put the splint on, clench the teeth, and keep the lips closed.

Without moving the subject's head, four x-ray exposures to the central part of the condyle were made. The exposures were standardized with the patient making maximum occlusion with the lips closed; the first two exposures were taken without the splint, and the last two with the pivoting appliance in position.

With the aid of a vertical and a horizontal line placed on the chassis, the highest point and a posterior point in the glenoid fossa as well as the highest point and the most anterior point in the articular condyle were located on each film (Fig 2).

The measurements of the distances between the two points previously selected by the radiologist was performed by an operator foreign to the study using a Vernier scale (Rostfrey Weyesberg) (Fig 3). For each subject, eight measurements were taken: four of the right TMJ and four of the left TMJ, without and with the splint.

Fig 2 Method in which points were located on each film.

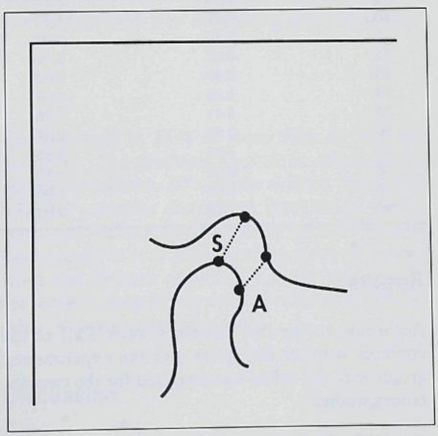


Fig 3 Point location and distances studied: S = superior distance, A = anterior distance.

Table 1 Superior Distance (mm) of the Right TMJ for Both Groups

Patient no.	With splint	Without splint
1	5.12	3.00
2	7.60	4.00
3	4.00	2.88
4	7.45	3.49
5	3.91	3.39
6	1.75	1.63
7	5.70	1.87
8	3.65	2.37
9	2.26	2.38
10	3.87	4.16
11	5.87	4.16
12	5.55	4.61
13	3.91	3.91
14	2.88	2.38
15	3.66	2.52
16	4.05	2.53
17	3.65	2.90
18	8.09	5.50
19	2.14	1.25
20	3.15	1.91

Table 2 Anterior Distance (mm) of the Right TMJ for Both Groups

Patient no.	With splint	Without splint
1	2.26	2.76
2	3.27	2.61
3	3.27	2.45
4	2.64	4.01
5	2.64	3.53
6	5.69	5.29
7	1.75	.98
8	2.76	3.00
9	2.21	1.51
10	2.45	2.26
11	4.78	5.74
12	2.14	2.52
13	2.40	2.64
14	2.52	2.87
15	2.14	3.27
16	1.87	1.51
17	1.87	2.38
18	5.29	2.40
19	2.76	3.02
20	3.38	3.89

Table 3 Superior Distances (mm) of the Left TMJ for Both Groups

Patient no.	With splint	Without splint
1	5.48	4.10
2	6.82	4.00
3	5.09	3.50
4	7.34	4.28
5	6.32	4.66
6	1.75	1.75
7	3.27	2.62
8	3.41	3.41
9	3.39	2.51
10	6.32	4.50
11	5.55	5.00
12	4.87	3.66
13	3.90	3.00
14	3.49	2.88
15	3.41	2.26
16	2.88	2.64
17	4.54	3.53
18	6.94	4.77
19	2.76	1.99
20	4.80	2.69

Table 4 Anterior Distances (mm) of the Left TMJ for Both Groups

Patient no.	With splint	Without splint
1	2.62	3.61
2	2.52	2.14
3	1.50	1.87
4	4.35	3.41
5	2.90	3.05
6	3.91	2.90
7	2.09	.75
8	2.38	3.09
9	2.00	1.63
10	2.99	2.00
11	5.67	6.17
12	1.87	1.49
13	4.66	3.92
14	3.53	3.15
15	2.01	4.16
16	2.05	2.27
17	3.15	2.37
18	4.27	2.45
19	3.09	3.15
20	2.38	2.45

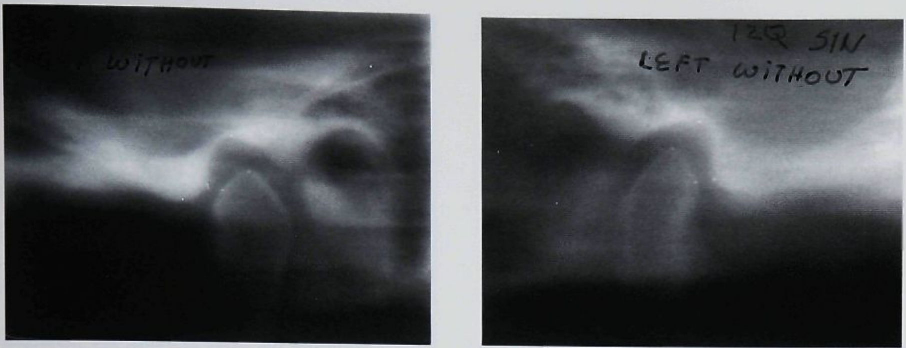
Results

According to the two variables, each TMJ of the controls without the splint and the experimental group with the splint was analyzed for the two distances studied:

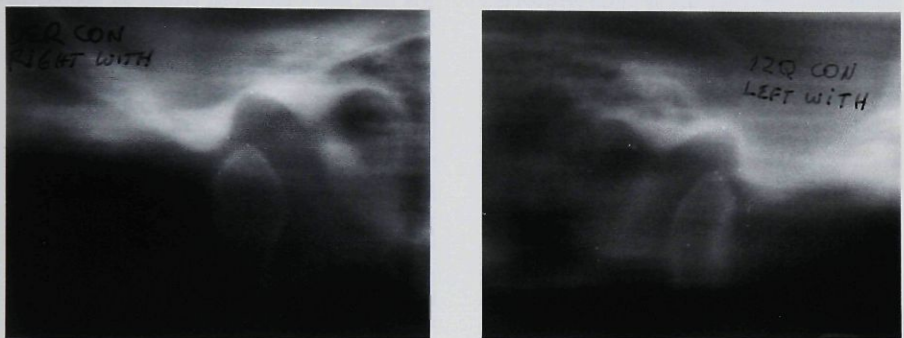
1. S = the highest point of the condyle to the highest point of the glenoid fossa.
2. A = the most anterior point of the condyle to the posterior point of the articular eminence.

In addition, four measurements were obtained to apply the ANOVA ($P < .05$):

1. SR = the superior distance, right TMJ (Table 1).
2. AR = anterior distance, right TMJ (Table 2).
3. SL = superior distance, left TMJ (Table 3).
4. AL = anterior distance, left TMJ (Table 4).



Figs 4a and 4b Linear tomograms of subject number 18's right *(a)* and left *(b)* TMJs, without the splint, clenching with the lips closed.



Figs 4c and 4d Linear tomograms of same subject's right *(c)* and left *(d)* TMJs with the pivoting splint in position, while clenching with the lips closed.

For the control group, the SR average measurement was 3.04 mm, and for the experimental group it was 4.41 mm. Thus, an average increase of 1.37 mm in the SR distance was noted, showing P = 6.165E-03 ($P < .05$) (Table 1).

The second measurement showed that the distance AR was shortened in 60% of the patients and increased in 40% of them (Figs 4a and 4b, Table 2).

For the control group, the SL average measurement was 3.39 mm, and it was 4.62 mm for the experimental group. Thus, an average increase of 1.23 mm in the SL distance was noted, showing P = 5.424E-03 ($P < .05$) (Table 3).

The fourth measurement showed that the distance AL was shortened in 45% of the patients and increased in 55% of them (Figs 4c and 4d, Table 4). The pivoting appliance affected the patients as follows: 30% of the subjects had a real bilateral condylar distraction (movement downward and backward); 35% of the subjects showed both condyles in a protruded position (a downward and forward position); and the last 35% of the subjects showed one condyle distracted and the other in a protruded position.

Discussion

The average temporalis forces in a "pure" mandibular closing movement have an upper and lightly oblique backward direction, corresponding to the middle portion of the muscle. The analysis was made on Katona's average mandibular scheme.[12]

It seems that a unique vector to represent the muscle force is an oversimplification. However, a muscle can be modeled by any number of vectors, which can be added to produce a unique vector of known points of application, direction, and magnitude.[13,14]

In a closing mandibular movement, the fulcrum over which the movement takes place is the complex relationship of the condylar head, the articular eminence, and the disc placed between them. In this way, a simple type II machine (in which the load lies between the force and the fulcrum) is established (Fig 5). The first lever arm (OR1) is the length of the mandible anteroposteriorly from the incisal edges of the mandibular anterior teeth (R1) to the rotational center of the system (O); the second lever arm (OR2) has its length between this rotational center (O) and the acrylic stop (R2).

When applying the P0 force of the vector of the temporalis muscle to the coronoid process, there is an effective lever arm (B1) that corresponds to the perpendicular distance in relationship to the vector of force from the fulcrum (O), which develops a momentum of force that tends to lift the whole mandibular body and, consequently, tighten the articular structures. If the acrylic stop is located on the direction of the vector of force P0 (P-0), the result is equal to zero, getting into rotational equilibrium, but if the stop is under this direction, the system reverses its direction trying to lower the condyle.

The masseter and medial pterygoid muscles, because of their insertions, cause a kind of strap that embraces the mandible at the gonial area and its anterior zone and create forces that cause a mandible to rise anteriorly and superiorly. Simplifying this scheme, it can be said that there are two vectors of force: one in the most anterior part of the muscles, and the other in the most posterior part of them (P1 and P2) (Fig 6). There are two lever arms in this muscle system. The mandible acts as a lever arm from the rotational center (O) to the incisal edges of the mandibular anterior teeth (OR1), and when the stop is in place, the second lever arm (OR2) is established from the rotational center to this stop. The most important factor in reversing the system of forces is locating the acrylic stop (R2) distal to the middle of the two vectors; or in any case shortening the length of the lever arm to get as close as possible to the rotational balance.

The orbicularis oris and the tongue muscles form a very important system that causes the anterior mandibular closing movement. With this valve closed, the forces of the system may be exerted as well as the forces of the whole body. It is important to note that for closing this valve, the forces of the suprahyoid and infrahyoid muscles are extremely important. The contraction of the orbicularis oris and the pressure caused by the tongue against the palate cause a rising movement (P3) of the anterior part of the mandible (R1). This effect is obtained if a space has been previously established between the teeth over which the movement can be exerted, being the fulcrum, the acrylic stop (R2), and the lever arm R1-R2 (Fig 7).

By integrating the three systems, the masseter system is completed when the acrylic stop blocks out the resultant force. The temporalis muscle pulls up the coronoid process and changes the fulcrum from the TMJ to the acrylic stop. This stop will turn into a pivot that creates an unbalanced situation and therefore lowers the condyle.

The orbicularis oris and tongue system, which closes the valve in the swallowing movement, creates a rising anterior vector of force that can work because of the interocclusal space created by the stops. The stops at this time become pivots over which the mandible rotates, raising the anterior portion and distracting the condyle (Fig 8).

A great force with a short lever arm can be neutralized with a small force and a long lever arm. With the pivots in position at the instant of swallowing, the effect is stronger for the orbicularis and tongue system than for the temporalis and masseter systems.

The differences in the data are possibly caused by variations of the individual's conditions, eg, Angle Class I, II, or III or gonial angle variation, that could change the muscle's vector of force direction and thus change the rotational center of the system. The second molar of these patients is not located behind this center (R2), and the system cannot be unbalanced.

The average increase of 1.37 mm in the SR distance, resulted in lowering of the right condyle for the group with the splint in 85% of the patients. The average increase of 1.23 mm in the SL distance resulted in lowering of the left condyle for the group in 90% of the patients.

A real condylar distraction was caused in 30% of the patients (downward and backward position), 35% of them had a bilateral protruded position (downward and forward position), and 35% had a combined situation (one condyle distracted and the other in a protruded position). This could be explained because the height of the stops was

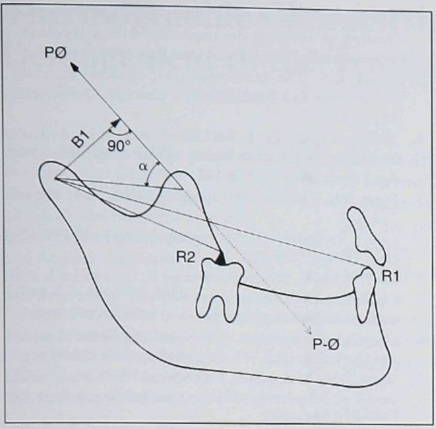


Fig 5 Temporalis forces and levers scheme.

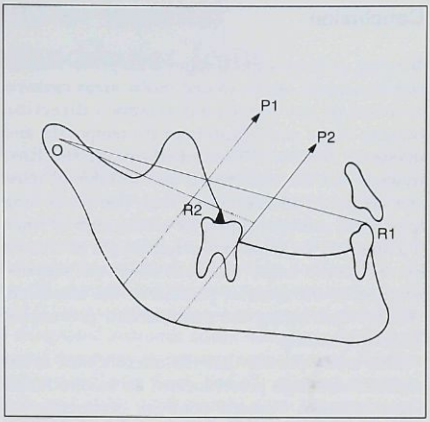


Fig 6 Masseter and medial pterygoid forces and levers scheme.

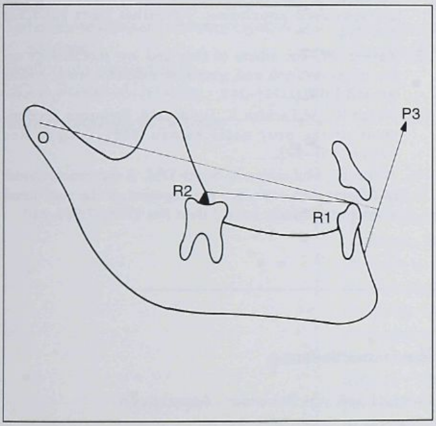


Fig 7 Orbicularis oris and tongue muscles forces and levers scheme.

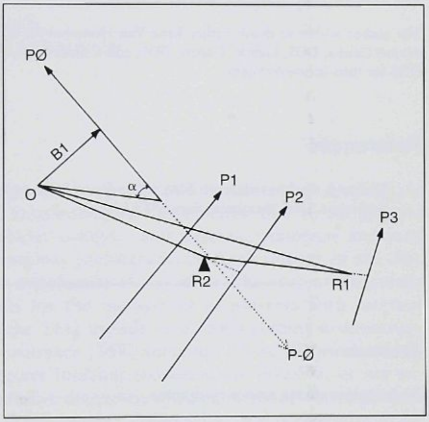


Fig 8 Integrated scheme of the forces and levers analyzed.

standardized for the study at 1.5 mm, but they were not individualized. Thus, for some subjects the stops were too high, which prevented the condyles from going into a physiological position from which the distraction could be exerted. This kept the subjects in an open mouth position that appears as a condylar protruded position. The subjects with one or both condyles in a protruded position could have presented a condylar distraction, but it could not be measured; the control group was without a splint, whereas the subject at the time of the experiment had the splint on, reaching two different condylar positions.

If the control group would have been the patients with the splint on, without clenching, and the experimental group was the same subjects with the splint on, clenching with the lips closed, then the results would have been better, because the comparative parameters would have been more reliable. Further research on this topic is recommended.

Conclusion

Wearing an interocclusal splint with pivots located simultaneously on the second molar areas causes a reversal of the rotational system's direction because of the neutralization of the temporalis and masseter forces. When swallowing, the lips, tongue, and the suprahyoid and infrahyoid muscles create an anterior force that, due to its long lever arm, produces a greater momentum of force if a space exists between the teeth, such as created by the acrylic stops. This will allow the superior rotation of the anterior portion of the mandible, thereby distracting the condyle and preventing TMJ overloading.

This study proved that the interocclusal splint with 1.5-mm-high pivots located on second molar areas caused a bilateral condylar distraction on 30% of the subjects.

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Resumen

Biomecanica de las placas pivotantes

Los efectos de las placas de tipo fulcro sobre las articulaciones témporomandibulares, no se conocen bien. Este estudio se llevó a cabo para evaluar y cuantificar la distracción condilar causada por el uso de una placa interoclusal superior con pivotes localizados simultáneamente sobre los segundos molares. El análisis se hizo por medio de tomografías lineales de las ATM de veinte estudiantes de Odontologia de la Universidad Javeriana. Los resultados estadisticos muestran un descenso condilar promedio de 1.3 mm. en el 87% de los pacientes ($P < 0.05$), durante máximo apretamiento, con los labios cerrados y con la placa en posición. El 30% de los pacientes hicieron distracción condilar bilateral; el 35% mostraban los dos cóndilos en posición protruida y el 35% de los pacientes mostraba una situación combinada.

Zusammenfassung

Biomechanik von Scharnier - Apparaturen

Der Effekt von Drehpunkt-Schienen auf das Kiefergelenk ist ungeklärt. Lineare Kiefergelenktomogramme von 20 Freiwilligen wurden analysiert. Das Ziel der Studie war die Auswertung und Quantifizierung der kondylären Distraktion, die durch diese Apparaturen erfolgt, wenn der Drehpunkt beidseits auf den zweiten Molaren gesetzt wird. Es resultierte, dass bei 87.5% der Probanden ($p < .05$) eine durchschnittliche kondyläre Verlagerung von 1.3mm nach unten erfolgt, wenn mit geschlossenen Lippen und eingesetzter Apparatur zusammengebissen wird. Eine beidseitige kondyläre Distraktion erfolgte bei 30% der Probanden, bei 35% zeigten beide Kondylen eine protrudierte Position und bei 35% lag eine Kombination von beidem vor.