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THE INFLUENCE OF STABILIZATION SPLINT ON CONDYLAR POSITION AND CRANIOFACIAL MORPHOLOGY

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The purposes of this study were : 1) to determine the normal range of CR-CO discrepancy in normal occlusion group ; 2) to evaluate the changes of condylar position and craniofacial morphology between centric relation and centric occlusion before and after stabilization splint therapy in malocclusion group outside the normal range of CR-CO discrepancy.

The normal occlusion group consisted of 80 subjects who had well-balanced faces and good occlusions with acceptable Class I molar relationship. They had not been treated orthodontically and had no signs or symptoms of temporomandibular joint dysfunction.

71 malocclusion patients enrolled for orthodontic treatment at the Department of Orthodontics, College of Dentistry, Chosun University comprised the malocclusion group, little variation of growth factor by the second molar eruption. They had CR-CO discrepancy beyond normal range and were subdivided into anterior-posteriorly -[25 Class I (0<ANB<4), 22 Class II (ANB ≥ 4), and 24 Class III (ANB ≤ 0)] ; vertically - [20 Normodivergentscy (30<SNGoMe<34), 33 Hyperdivergency (SNGoMe ≥ 34), and 18 Hypodivergency (SNGoMe ≤ 30)] ; and sexually - [26 Male and 45 Female]. For malocclusion group, stabilization splint with mutually protected type of occlusal scheme was applied for three months.

Panadent articulators, Panadent condylar position indicator (CPI), and lateral headfilm were used to investigate the influence of stabilization splint on condylar position and craniofacial morphology.

The results of this study were as follows :

1. The amounts of CR-CO discrepancy in normal occlusion were that the antero-posterior component (△X) was 0.56 ± 0.46mm (Male:0.63 ± 0.42mm, Female:0.49 ± 0.50mm) ; the supero-inferior component (△Y) was -0.75 ± 0.48mm (Male:-0.76 ± 0.52mm, Female:-0.73±0.43mm) ; and the transverse component (△Z) was -0.33 ±0.28mm (Male : -0.38 ± 0.29mm, Female:-0.31 ± 0.27mm).
2. The condylar position was in normal range after stabilization splint therapy.
3. The mandible was always rotated infero-posteriorly after stabilization splint therapy.
4. Antero-posteriorly, Class III malocclusion responded very well to the stabilization splint therapy.
5. Vertically, Hyperdivergency responded very well to the stabilization splint therapy.
6. Sexually, Male responded very well to the stabilization splint therapy.

key words : CR-CO discrepancy, stabilization splint, Panadent articulator, CPI(condylar position indicator)

In traditional orthodontic diagnosis and treatment planning, the goal was only to achieve maximum intercuspation in a static occlusion. This has been based on static materials - plane models, which were hand-held, and lateral headfilms in CO(centric occlusion, maximum intercuspation regardless to condylar position). But considering that the challenge to the orthodontist is to establish a functionally stable perfect occlusion with good facial esthetics, it cannot be regarded as an adequate diagnostic data. Hand-held models provide only how teeth contact or fit together and lateral headfilms in CO are necessary, but insufficient. Most often a case mounted in CR(centric relation, seated condylar

position) may call for a different orthodontic treatment plan from the same case diagnosed from CO.

If the goal of orthodontic treatment is to place teeth in harmony with temporomandibular joint, we must diagnose from centric relation position of the condyles. However, without the use of the articulator and the stabilization splint, it is usually not possible to capture a true, stable, repeatable centric position in the first place, no matter what the technique is[21,22]. When a fulcrum is present on the last tooth in centric related occlusion(CRO) due to occlusal interference, the patient tries to avoid the occlusal interference by neuromuscularly repositioning the mandible. This leads to vertical distraction of the condyles with a forward and often lateral posturing of the mandible[38].

However, an ideal stable occlusion does not require neuromuscular adaptation to avoid premature contacts and interferences. In order to have an ideal occlusion, the occlusion needs to be in complete harmony with the neuromuscular system and the temporomandibular articulation. In this view point, CR can be considered the most important spatial relationship of the mandible to the maxilla as a reference for orthodontic diagnosis and treatment planning. For this purpose, using the articulator and the stabilization splint must be the starting point of all orthodontic treatments and the basis for functional occlusion concept which is the ultimate goal of the occlusion and the maxillo-mandibular relationship without occlusal interference which prevents the functional movement of the mandible, and also without being physiologically harmful for the function and the health of the stomatognathic system[21,30,38].

Stabilization splint therapy precedes orthodontic intervention to enable the operator to find a "true" centric(which is stable and comfortable); to test the patient's response to a change in the occlusion, prior to embarking upon a complex course of occlusal therapy; and finally, to see if the centric relation position can be stabilized[22].

The importance of mounted models in CR to examine the changes of condylar position and make a complete diagnosis has been reported previously [5,6,10,12,13,14,19,21,23,30,38]. Williamson et al.[33] reported that a bite plane resulted in a significant antero-superior directional changes in a terminal hinge axis location. They insisted that the lack of the bite plane could have allowed an aberrant neuromuscular pattern to remain and therefore, a combination of aberrant muscle activity and ligamental limits might have resulted in the tendency for a postero-inferior displacement in the hinge axis location.

Previous attempts that took CR headfilm to diagnose from centric relation position have been reported. Wood[40] photographed routine CO headfilms using "shadowgraph technique" to compare and analyze the differences between CO and CR. Centrically related cephalometrics and mounted models offered an accurate, reproducible maxillomandibular relationship that could not be found with hand-held models and CO headfilms. Williamson et al.[34] reported that in cephalometric comparisons between CO and CR, the largest discrepancy was seen in Class II malocclusion, though the differences, with the exception of few cases, were slight. Slavicek originated and Corbett & Williams modified CO-CR conversion which allowed transfer of information obtained from mounted casts. Shildkraut et al.[27] converted CO headfilm to CR headfilm for diagnosis from centric relation position using the MPI (mandibular position indicator). They reported that the condyles were always vertically distracted and most often positioned distally when the teeth were in CO.

A CR headfilm, not an estimated headfilm, is indispensable in revealing the true maxillomandibular relationship. A CR headfilm can be obtained after the mandible is stabilized on a stabilization splint before active orthodontic treatment.

This study presents three-dimensional evaluation on the influence of stabilization splint on condylar position and craniofacial morphology using the Panadent articulator, the CPI(condylar position indicator, Panadent Corp., Grand Terrace, Calif.), and lateral headfilms taken before & after stabilization splint therapy. The Panadent articulator and the CPI enables clinicians to determine, record, and compare the positional changes of the condyle between CR and CO in all three spatial planes.

The purposes of this study were : 1) to determine the normal range of CR-CO discrepancy in normal occlusion group ; 2) to evaluate the changes of condylar position and craniofacial morphology before & after stabilization splint therapy in malocclusion group outside the normal range of CR-CO discrepancy.

Table 1. Number, sex, and age distributions of normal and malocclusion groups

	Number			Age(Years)	
	Total	Male	Female	Mean	Range
Normal occlusion	80	40	40	22.9	19.4-28.9
Malocclusion	71	26	45	17.5	12.3-25.2

Table 2. Antero-posterior classifications of malocclusion group

	Class I	Class II	Class III	Sum
Number	25	22	24	71

Table 3. Vertical classifications of malocclusion group

	Normodivergency	Hyperdivergency	Hypodivergency	Sum
Number	20	33	18	71

MATERIALS AND METHODS

1. MATERIALS

1) Normal occlusion group

80 students at the dental college of Chosun University volunteered for this study. They had well-balanced faces and good occlusions with acceptable Class I molar relationship. They had not recived orthodontic treatment and had no signs or symptoms of temporomandibular joint dysfunction. The number, sex, and age distributions are shown in Table 1.

2) Malocclusion group

71 malocclusion patients enrolled for orthodontic treatment at the Department of Orthodontics, College of Dentistry, Chosun University comprised the malocclusion group, little variation of growth factor by the second molar eruption. They had CR-CO discrepancy beyond normal range.

For comparisons, 71 patients were subdivided into anterior-posteriorly - [25 Class I(0<ANB<4), 22 Class II(ANB ≥ 4), and 24 Class III(ANB ≤ 0)] ; vertically - [20 Normodivergentscy(30<SNGoMe<34), 33 Hyperdivergency(SNGoMe ≥ 34), and 18 Hypodivergency (SNGoMe ≤ 30)] ; and sexually - [26 Male and 45 Female].

The number, sex, age distributions are shown in Table 1-3.

2. METHODS

1) CO & CR wax bite registration

CO wax bite was registered in the state of maximum intercuspation with a single layer of dead-soft pink bite registration wax(10X wax, Moyco Industries Inc., Philadelphia, Penn.).

CR wax bite was registered with Delar bite registration wax(Delar Corp., Lake Oswego, Ore.) and divided in two sections. The anterior section rolled four or five thickness of wax and cut slightly wider than maxillary intercanine width. The antero-posterior dimension depended on the amount of overjet. There should be 2 or 3mm posterior clearance at the first contact area. The posterior section rolled one or two thickness of wax and extended silghtly buccal to the buccal surfaces of the upper second premolar and first molar to allow very little horizontal overlap that the cheeks could not distort.

CR wax bite registration was taken according to Dyer's[3,4] "Muscular seated power centric" and Roth's[21] "3 finger tripoding method" to capture CR position clinically. The patient was seated in the dental chair, and the chair was reclined to a 45° angle. The operator guided the mandible, applying chin point pressure at pogonion to prevent protrusion, supporting the angles of the mandible in a superior direction, and asking the patient to relax and close slowly. The power centric registration refers to the use of the patient's power centric muscles(masseter, medial pterygoid, and superior heads of the lateral pterygoids), not the operator's guidance.

Bite registration wax should be "dead-soft" when used. It is softened in a controlled water bath of 135-140 degrees Fahrenheit or 60 degrees Celsius. After the bite registration, it was cooled with the air syringe, carefully removed and hardened in ice water. The wax registration was trimmed with a sharp scalpel in running water to remove undercuts, soft

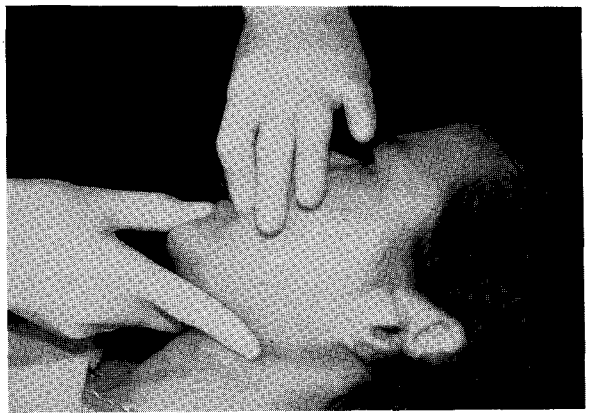


Fig. 1. Muscular seated power centric registration using 3 finger tripoding method

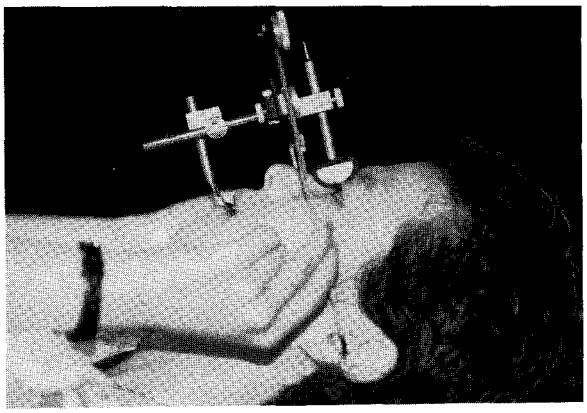


Fig. 2. Estimated face bow transfer

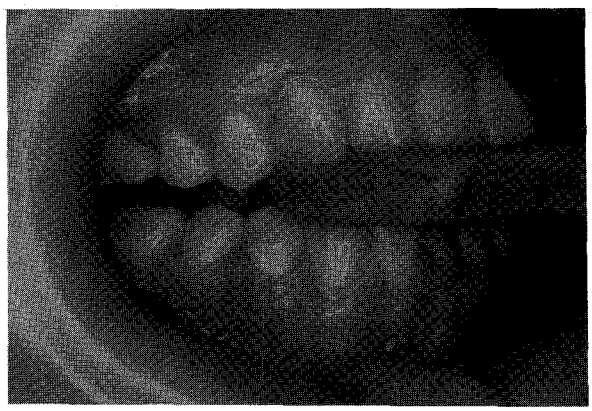


Fig. 3. Anterior CR wax bite registration with Delar blue wax

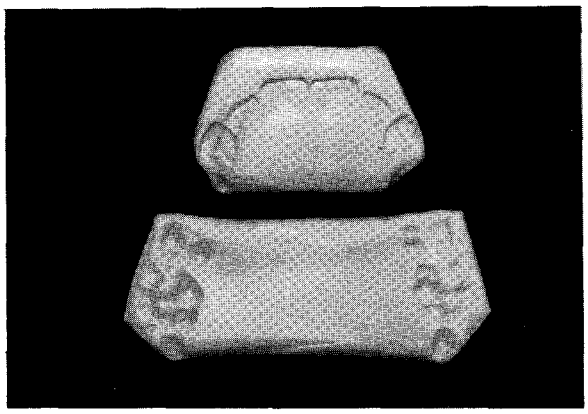


Fig. 4. 2-piece Delar blue wax taken in CR

tissue contacts, and interproximal areas, while maintaining indexing of cusp tips and incisal edges (Fig. 1,3,4).

2) Estimated facebow mounting

Maxillary and mandibular impressions were made using an irreversible hydrocolloid material(Type I-Fast set Alginate, Meer Dental Corp., Canton, MI) in nonperforated rimlock stock trays(Superior Co.). The maxillary and mandibular alginate impressions were poured up immediately using type IV high-strength dental stone(Vel-Mix, Kerr Manufacturing Co., Romulus, MI). Separation proceeded within one hour after initial set of the stone.

The maxillary stone cast was mounted on the upper member of the Panadent articulator(PSL type, Panadent Corp., Grand Terrace, Calif.) using the ear facebow transfer(Panadent Co.) provided to locate the estimated hinge axis. The facebow was oriented on a line parallel to Frankfort horizontal plane by employing soft tissue nasion as the anterior reference point. The mandibular cast was related to the upper cast with the CR bite registration.

All casts were mounted on the articulator using fast-set mounting stone(Snow White Plaster #2, Kerr Manufacturing Co., Romulus, MI)(Fig. 2,5,6).

3) Fabrication of stabilization splint

Full coverage stabilization splint was made according to Roth's fabrication method[22]. It was constructed by indirect method on the articulator with self-curing resin(Caulk Co.). Occlusal scheme of the

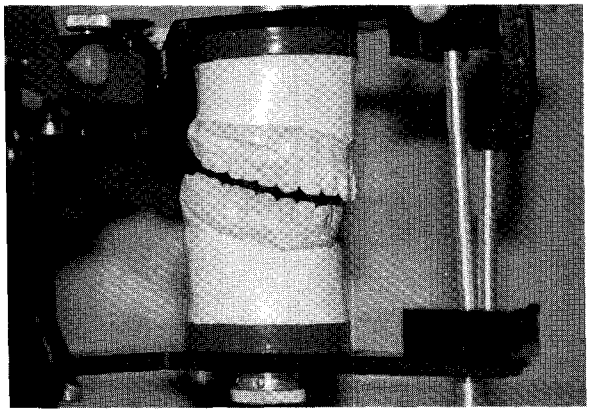


Fig. 5. CR mounted models(Rt. view)

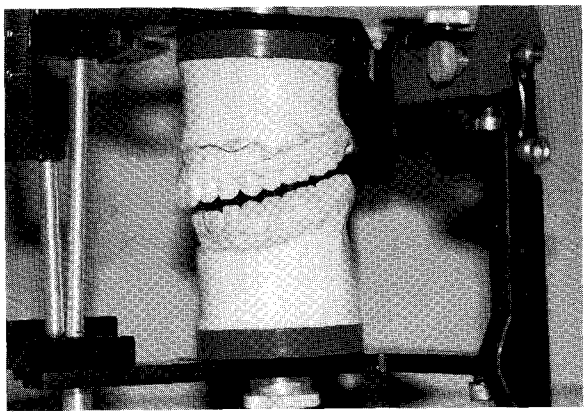


Fig. 6. CR mounted models(Lt. view)

Fig. 7. Stabilization splint in mouth(Rt. view)

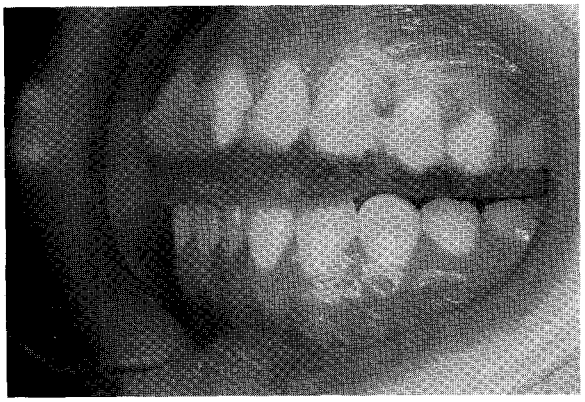


Fig. 8. Stabilization splint in mouth(Lt. view)

stabilization splint based on mutually protected occlusion. The acrylic against which the mandibular anterior teeth occluded was adjusted to create a cuspid and incisal guide ramp which resulted in an immediate posterior disclusion. Therefore, all posterior working and balancing interferences were eliminated.

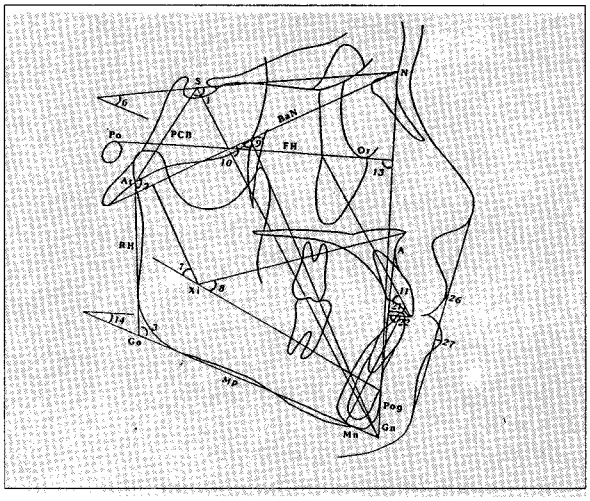
The centric stops for all lower posterior buccal cusps(cusp tip indents only) and the posterior eccentric disclusion were evaluated using .0005 inch shim stock(GHM Co.). The pressure of all posterior centric stops was equalized and evenly contacted. The shim stock was not removed until the eccentric movement of the mandible was initiated.

As the condyle repositioned upward by stabilization splint therapy, contact points of teeth on the splint changed. Then, whenever the splint was unstable, it was adjusted, or if not possible, remade. The patients were instructed to wear it 24 hours for three months(Fig. 7,8).

4) Measurement of condylar position

For each mountings, centric slides(from CR to CO) were assessed in the sagittal, vertical, and transverse plane using a CPI before & after stabillization splint therapy. This device can measure the three-dimensional changes in the condylar position between CR and CO.

The CPI recording paper(Panadent Co.) was attached to the right and left sliding blocks in the sagittal plates and the transverse sliding blocks in the transverse plate. The condylar position was recorded on the coordinate of(X,Y,Z). The amounts of CR-CO discrepancy measured on the basis of(0,0,0) coordinate in CR were for the antero-posterior component($\triangle$X), anterior displacements(+), or posterior displacements (-); for the supero-inferior component($\triangle$Y), superior



CEPHALOMETRIC LEGEND

※ *ANGLES*
1. NSAr, 2. SArGo, 3. ArGoMe, 4. ANB(NS),
5. SNB(NS), 6. SNGoMe, 7. MA, 8. LFH,
9. FA, 10. YA, 11. IIA, 12. AC(NS), 13. FD
14. FHGoMe,
※ *RATIO*
15. PCB : RH(NS), 16. FHR(NS)
※ *INDEX*
17. ODI(NS), 18. APDI(NS)
※ *LINEAR MEASUREMENTS*
19. OB(NS), 20. OJ(NS), 21. U1APog, 22. L1APog,
23. LAFH(NS), 24. Wits(NS), 25. PogNV(NS),
26. Ulip-E, 27. Llip-E, * NS : not shown

Fig. 9. Cephalometric landmarks used : angles, ratios, and linear measurements(left). MA=mandibular arc ; FA=facial axis ; LFH=lower facial height ; IIA=interincisal angle ; YA=Y axis ; AC=angle of convexity ; FD=facial depth ; FHR=facial height ratio ; ODI=overbite depth indicator(A-B to mandibular plane angle ±palatal plane to FH plane angle) ; APDI=anteroposterior dysplasia indicator(facial plane to FH plane angle±A-B plane to facial plane angle±palatal plane to FH plane angle) ; OB=overbite ; OJ=overjet ; LAFH=lower anterior facial height ; PogNV=pogonion to nasion perpendicular ; Ulip-E=upper lip to esthetic line:Llip-E=lower lip to esthetic line ; Wits="wits" appraisal.

displacements(-), or inferior displacements(+); for the transverse component(△Z), right-laterotrusive displacements(+), or left-laterotrusive displacements(-). For statistical analysis, the value of △Z was calculated as the absolute value. The position of the point recorded was measured to the nearest 0.1mm using tenfold scale lupe(Peak Co.).

5) Cephalometric analysis

All initial films were traced on frosted acetate and subsequently digitized on a digitizing board. Landmarks, as shown in Fig. 9., were located on each tracing prior to digitizing. After three months, of stabilization splint therapy, lateral headfilms were retaken and retraced on frosted acetate and subsequently digitized on the digitizing board.

The Quick Ceph Image(QCI) program(Orthodontic Processing, 1990-1994 by Dr. Günther Blaseio) was used to calculate the various skeletal and dental measurements described in Fig. 9.

Only the measurements of the mandibular position were chosen for the purpose of this study.

6) Statistical analysis

The means and standard deviations for each sample were calculated.

The paired *t* test was used to test the differences between condylar position before & after stabilization splint therapy for : 1) Class I, 2) Class II, 3) Class III, 4) Normodivergency, 5) Hyperdivergency, 6) Hypodivergency, 7) Male, 8) Female, and 9) total malocclusion group(n=71).

The Student's *t* test was preformed to compare the differences in CPI records between : 1) Male and Female in normal occlusion group, 2) Male and Female before stabilization splint therapy, 3) Male and Female after stabilization splint therapy, 4) normal occlusion group and after stabilization splint therapy, and also 5) to find the differences of cephalometric records between Male and Female before & after stabilization splint therapy.

ANOVA(Analysis of Variance) and Scheffe tests were used to test the differences between condylar position before & after stabilization splint therapy according to CPI and cephalometric records for: 1) Class I, Class II, and Class III; 2) Normodivergency, Hyperdivergency, and Hypodivergency.

Table 4. Means and standard deviations of the amounts of CR-CO discrepancy for normal occlusion group, and malocclusion group before & after stabilization splint therapy by CPI records

	X						Y						Z	
	R		L		R+L/2		R		L		R+L/2			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male	0.60	0.55	0.66	0.43	0.63	0.42	-0.73	0.68	-0.78	0.45	-0.76	0.52	-0.38	0.29
Female	0.36	0.59	0.62	0.61	0.49	0.50	-0.53	0.51	-0.94	0.52	-0.73	0.43	-0.31	0.27
Both	0.48	0.58	0.64	0.52	0.56	0.46	-0.63	0.61	-0.86	0.49	-0.75	0.48	-0.33	0.28
TMBS	0.89	0.80	0.76	1.01	0.83	0.75	-1.45	0.95	-1.64	0.94	-1.55	0.89	-0.42	0.39
TMAS	0.45	0.48	0.67	0.70	0.56	0.48	-0.68	0.70	-0.81	0.60	-0.75	0.58	-0.22	0.17

Male, Female, Both : normal occlusion group
TMBS: total malocclusion group before stabilization splint therapy
TMAS: total malocclusion group after stabilization splint therapy

Table 5. Changes fo the amounts of CR-CO discrepancy before (△X1,△Y1,△Z1) & after (△X2,△Y2,△Z2) stabilization splint therapy with mean differences for malocclusion group by CPI records

	△X2-△X1			△Y2-△Y1			△Z2-△Z1
	R	L	R+L/2	R	L	R+L/2	
Class I	-0.03	-0.08	-0.02	0.52*	0.64**	0.58*	0.20**
Class II	-0.82**	-0.24	-0.53*	0.54*	0.40*	0.47**	0.21**
Class III	-0.53**	-0.14	-0.33*	1.24***	1.43***	1.34***	0.18
Normodivergency	-0.21	-0.33	-0.06	0.69**	0.78***	0.73***	0.13*
Hyperdivergency	-0.68**	-0.50*	-0.59**	0.98***	1.11***	1.04***	0.29***
Hypodivergency	-0.43	-0.06	-0.25	0.42	0.36	0.39*	0.13
Male	-0.37*	-0.22	-0.08	0.21	0.54**	0.37*	0.28**
Female	-0.49**	-0.27	-0.38*	1.06***	1.01***	1.03***	0.15**
Total (n=71)	-0.44	-0.10	-0.27	0.77**	0.65**	0.80**	0.20

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 6. Comparisons of the amounts of CR-CO discrepancy between normal occlusion group & malocclusion group after stabilization splint therapy by CPI records

	X			Y			Z
	R	L	R+L/2	R	L	R+L/2	
Male	-	-	-	-	-	-	*
Female	-	-	-	-	**	-	-
Bote	-	-	-	-	-	-	**

* P < 0.05, ** P < 0.01, - No significant difference

RESULTS

1. Condylar position

1) The amounts of CR-CO discrepancy in normal occlusion were that the antero-posterior component (△X) was 0.56 ± 0.46mm(Male:0.63 ± 0.42mm, Female : 0.49 ± 0.50mm) ; the supero-inferior component(△Y) was -0.75 ± 0.48mm(Male:-0.76 ± 0.52mm, Female:-0.73±0.43mm); and the transverse component(△Z) was -0.33 ±0.28mm(Male: -0.38 ± 0.29mm, Female:-0.31 ± 0.27mm)(Table 4).

2) The means and standard deviations of the amounts

Table 7. Comparisons of the amounts of CR-CO discrepancy for each group using CPI records

	X			Y			Z
	R	L	R+L/2	R	L	R+L/2	
STN (n=80)	-	-	-	-	-	-	-
SBSM(n=71)	-	-	-	*	-	-	-
SASM(n=71)	-	-	-	*	*	*	-

* $P < 0.05$, - No significant difference
STN : sexual differences of the total normal occlusion group
SBSM : sexual differences before stabilization splint therapy in the total malocclusiongroup
SASM : sexual differences after stabilization splint therapy in the total malocclusion group

found in the right Y component before stabilization splint therapy and in all Y components after stabilization splint therapy.
There was no statistical significance in the rest of the components(Table 7).

6) In comparison of the amounts of CR-CO discrepancy among Class I, Class II, Class III, and Normodivergency, Hyperdivergency, Hypodivergency before & after stabilization splint therapy, there were statistical significances in the right component of X between Class I and Class II, in the left component of X between Hyperdivergency and Hypodivergency, in the R+L/2 component of X between Normodivergency and Hyperdivergency, in

Table 8. ANOVA (Analysis of Variance) and Scheffe tests for each contrast group according to CPI records

		Class I vs Class II	Class I vs Class III	Class II vs Class III	Normodivergency vs Hyperdivergency	Normodivergency vs Hypodivergency	Hyperdivergency vs Hypodivergency
X	R	**	-	-	-	-	-
	L	-	-	-	-	-	*
	R+L/2	-	-	-	*	-	-
Y	R	-	*	-	-	-	-
	L	-	-	-	-	-	*
	R+L/2	-	**	**	-	-	-
Z		-	-	-	-	-	-

* $P < 0.05$, ** $P < 0.01$, - No significant difference

of CR-CO discrepancy for malocclusion group before & after stabilization splint therapy by CPI records are shown in Table 4.

3) The changes of the amounts of CR-CO discrepancy before & after stabilization splint therapy with the mean value for malocclusion group are shown in Table 5. Especially, the statistical significances were shown in all Y components except the right and left Y component of Hypodivergency.

4) The comparison of the amounts of CR-CO discrepancy between normal occlusion group and malocclusion group after stabilization splint therapy by CPI records are shown in Table 6. Statistical significances were shown in the Z component of Male and both group, and in the left Y component of Female.

5) In sexual comparison, statistical significances were

the right component of Y between Class I and Class III, in the left component of Y between Hyperdivergency and Hypodivergency, and in the R+L/2 component of Y between Class I and Class III, and also between Class II and Class III(Table 8).

2. Craniofacial morphology

1) The changes of craniofacial morphology before & after stabilization splint therapy with mean differences for each malocclusion group by cephalometric records are shown in Table 9. The statistical significances were shown in OB, ANB, Wits of Class I; OB, OJ, U1APog, LAFH, NSAr, APDI of Class II; PogNV, OB, OJ, LFH, AC, U1APog, LAFH, SArGo, ArGoMe, SNB, ANB, Wits

Table 9. Changes of the caniofacial morphology before & after stabilization splint therapy with mean differences for each malocclusion group by cephalometric records (before-after)

	Class I	Class II	Class III	Normodivergency	Hyperdivergency	Hypodivergency	Male	Female
PogNV	0.52	0.16	1.28*	0.48	0.19	0.02	0.29	0.48
OB	0.60**	0.89**	0.96**	1.12**	0.80**	0.49*	0.72**	0.86***
OJ	-0.18	-0.83*	-1.17*	-0.91	-0.73	-0.49	-1.14**	-0.48
Ulip-E	-0.18	-0.39	-0.48	-0.01	-0.60*	-0.04	-0.10	-0.43**
LFH	-0.28	-0.68	-1.48**	-0.04	-1.01*	-0.87	-0.59	-0.63
MA	0.83	0.20	0.69	2.55**	2.62*	1.49*	0.20	0.11
IIA	0.18	1.30	0.32	0.15	0.24	1.46	0.20	0.58
YA	-1.60	-2.29	-0.13	-1.83	-1.70	-0.39	-1.52	-1.20
AC	-0.28	-0.47	-2.93*	-0.61	-2.57*	-0.48	-2.32*	-0.20
U1APog	-0.08	-0.82*	-0.67**	-0.30	-0.09	-1.25***	-0.75**	-0.28
L1APog	-0.05	-0.11	-0.14	-0.30	-0.16	-0.56	-0.22	-0.10
LAFH	-0.57	-2.05**	-2.11***	-1.10*	-1.57***	-2.12***	-2.00***	-1.28***
SNGoMe	-0.23	-0.39	-0.51	-0.58	-0.50*	-0.55	-0.43	-0.87
FHGoMe	-0.12	-0.17	-0.44	-0.37	-0.29	-0.74	-0.33	-0.14
FA	0.47	0.12	1.63	0.02	1.35	0.27	1.05	0.32
FD	0.21	0.15	0.33	0.35	0.13	0.63	0.16	0.08
NSAr	-0.12	-0.77*	-0.37	-1.06	-0.52	-0.28	-1.30**	-0.11
SArGo	-0.20	-1.61	-0.74*	-0.68	-1.37*	-0.32	-0.71	-0.66
ArGoMe	-0.30	-0.12	-0.89**	-0.50*	-0.76	-0.16	-0.31	-0.07
SNB	0.27	0.94	0.44**	0.74	0.01	0.21	0.21	0.50
FHR	0.18	0.18	0.21	0.20	0.27*	0.46	0.57**	0.03
PCB:RH	1.26	0.30	1.18	2.08**	2.00*	0.81	1.77	1.02
ANB	-0.47**	-0.06	-0.80**	-0.27	-0.87**	-0.34	-0.53	-0.05
Llip-E	-0.15	-0.19	-0.18	-0.72*	-0.30	-0.10	-0.25	-0.05
Wits	-0.87*	-0.01	-0.83*	-0.90*	-0.67	-0.02	-0.81**	-0.46
ODI	0.34	0.96	0.33	0.14	0.21	0.91	0.09	0.05
APDI	0.74	1.50***	0.14	0.23	2.34*	1.55**	1.07	0.52

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, - No significant difference

of Class III ; OB, MA, LAFH, ArGoMe, PCB:RH, Llip-E, Wits of Normodivergency ; OB, Ulip-E, LFH, MA, AC, LAFH, SNGoMe, SArGo, FHR, PCB:RH, ANB, APDI of Hyperdivergency ; OB, MA, U1APog, LAFH, APDI of Hypodivergency; OB, OJ, AC, U1APog, LAFH, NSAr, FHR, Wits of Male ; and OB, Ulip-E, LAFH of Female.

2) In comparison of cephalometric records before & after stabilization splint therapy among Class I, Class II, Class III, and Normodivergency, Hyperdivergency, Hypodivergency, and between Male and Female, there were statistical significances in LFT between Class I and Class III ; in MA between Normodivergency and Hyperdivergency, and also between Hyperdivergency and Hypodivergency ; in AC between Class I and Class III, and Class II and Class III, and also between Male and Female ; in U1APog between Hyperdivergency and Hypodivergency ; in LAFH between Class I and Class II, and also Class I and Class III ; in SNGoMe between Normodivergency and Hyperdivergency; in NSAr and FHR between Male and Female ; in PCB : RH between Normodivergency and Hyperdivergency, and also between Normodivergency and Hypodivergency ; in ANB between Class I and Class III, Normodivergency and Hyperdivergency, and also between Hyperdivergency and Hypodivergency, in Llip-E between Normodivergency and Hyperdivergency ; in APDI between Class II and Class III, and also between Male and Female(Table 10).

DISCUSSION

As the functional occlusion concept has been concretely applied to orthodontic treatment since 1970s,

Table 10. ANOVA (Analysis of Variance) and Scheffe tests for each contrast group, and student's t tests for Male vs Female malocclusion group according to cephalometric records

	Class I vs Class II	Class I vs Class III	Class II vs Class III	Normodivergency vs Hyperdivergency	Normodivergency vs Hypodivergency	Hyperdivergency vs Hypodivergency	Male vs Female
PogNV	-	-	-	-	-	-	-
OB	-	-	-	-	-	-	-
OJ	-	-	-	-	-	-	-
Ulip-E	-	-	-	-	-	-	-
LFH	-	*	-	-	-	-	-
MA	-	-	-	*	-	*	-
IIA	-	-	-	-	-	-	-
YA	-	-	-	-	-	-	-
AC	-	**	**	-	-	-	*
U1APog	-	-	-	-	-	*	-
L1APog	-	-	-	-	-	-	-
LAFH	*	*	-	-	-	-	-
SNGoMe	-	-	-	*	-	-	-
FHGoMe	-	-	-	-	-	-	-
FA	-	-	-	-	-	-	-
FD	-	-	-	-	-	-	-
NSAr	-	-	-	-	-	-	**
SArGo	-	-	-	-	-	-	-
ArGoMe	-	-	-	-	-	-	-
SNB	-	-	-	-	-	-	-
FHR	-	-	-	-	-	-	*
PCB:RH	-	-	-	**	**	-	-
ANB	-	**	-	**	-	**	-
Llip-E	-	-	-	**	-	-	-
Wits	-	-	-	-	-	-	-
ODI	-	-	-	-	-	-	-
APDI	-	-	*	-	-	-	*

* $P < 0.05$, ** $P < 0.01$, - No significant difference

the correct position of the condyle and the maintenance of CR position when the teeth occlude in CO, which produces the greatest neuromuscular efficiency during function and stability in a static position have been emphasized. There has been considerable controversy regarding its nature, position, and reproducibility[1,2,7,9,11,17,36]. Stuart[31] defined CR as the rearmost, uppermost, and midmost position of the condyles in their respective fossa with the mandible at its most closed position. For years, Dyer[3] defined that CR must be positioned at the supero-anterior position of the condyles in the glenoid fossa, not the maxillomandibular relationship when the condyle is positioned within the condylar fossa at the rearmost, uppermost and midmost of the glenoid fossa. Dawson[2] described CR as the maxillomandibular relationship in which the properly aligned condyle and disk were in the most superior position in contact with the posterior surface of the articular eminence. According to Posselt[16] and Ramfjord et al.[17], CR is influenced by numerous factors, one of which is the neuromuscular system. This system has a strong adaptive capacity to permit the function and protection of the gnathostomatic system. Deflective occlusal contacts will induce conditioning of the neuromuscular system, which will be constantly reinforced with each closure through proprioceptive feedback.

Recently, centric relation is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterosuperior position against the slopes of the articular

eminence, irrespective of tooth position or vertical dimension. It can be clinically confirmed and reproduced[1,2,35].

There has been also considerable controversy regarding CR-CO discrepancy[1,2,7,9,11,17,36].

Gnathologic concept[8] considered it as a pathological state and insisted "point centric", while Pankey-Mann-Schuyler(PMS) concept[24,25] regarded it as a physiological state and insisted "long centric" which allowed freedom in centric(or wide centric). Posselt[15] reported reduction in its range to 1.25mm, Schuyler[24,25] to 1.0mm, Ramfjord and Ash[17] to 0.5-0.8 mm, Dawson[2] to 0.2mm, and Ramfjord[18] to 0.2mm. The difference between the two concepts had little clinical meaning. In addition, in the PMS concept which insisted long centric recognized only a little antero-posterior freedom and no vertical and transverse discrepancy.

By using SAM articulator(MPI), Denar articulator (Vericheck)[26,37], Buhnergraph, and Panadent articulator(CPI) to measure CR-CO discrepancy, 3-dimensional evaluation of the condylar position was possible.

At the completion of orthodontic treatment, the amounts of CR-CO discrepancy should be within 1.0mm antero-posteriorly and infero-superiorly, and within 0.3mm transversely[21,28,32,38,39]. The reduction of zero is not practical and desirable , but the reduction can be obtained with an occlusal adjustment[32]. Dr. Brian Wong(personal communication) examined 250 pretreatment patients and found the amounts of CR-CO discrepancy to be 0.7mm antero-posteriorly, 1.0mm vertically, and 0.3mm transversely.

In this study, the amounts of CR-CO discrepancy of normal occlusion group were 0.56 ± 0.46mm antero-posteriorly, -0.75 ± 0.48mm vertically, and -0.33 ± 0.28mm transversely. There was no statistical significance between Male and Female(Table 5,7). These were similar to those of Dr. Brian Wong's.

In the malocclusion group, the amounts of CR-CO discrepancy after stabilization splint therapy were 0.56 ± 0.48mm anterior-posteriorly, -0.75 ± 0.58mm vertically, and -0.22 ± 0.17mm transversely. There was no difference in comparison of those of normal occlusion group(Table 4). This suggests that stabilization splint is useful in correcting and stabilizing condylar position. Also, the amounts of CR-CO discrepancy before stabilization splint therapy were 0.83 ±0.75mm antero-posteriorly, -1.55 ± 0.89mm vertically, and -0.42 ± 0.39mm transversely, which means that the condyle is always vertically distracted and most often positioned distally when the teeth interfere in CO(Table 4). It also signifies that the amount of vertical CR-CO discrepancy is much greater than antero-posterior CR-CO discrepancy. In comparison of CR-CO discrepancy before & after stabilization splint therapy in the total malocclusion group, there was a statistical significance only in the Y components(Table 5). This means stabilization splint is useful in correcting vertical discrepancy of condyles. As a result, to reveal the vertical discrepancy and to detect the condylar position in the beginning of orthodontic treatment, all cases should be diagnosed from CR position using the articulator and stabilization splint.

In comparison of the amount of CR-CO discrepancy before & after stabilization splint therapy in each group, there was a statistical significance antero-posteriorly, vertically, and transversely in Class II, Hyperdivergency, and Female groups(Table 5). However, Hypodivergency had statistical significance only in the R+L/2 component of Y. This means stabilization splint is less effective to Hypodivergency, but more useful to other groups, especially such as Class II, Hyperdivergency, and Female group. The changes accompanied by stabilization splint therapy are to eliminate of muscle spasms or contractures; to eliminate excess fluid in the joint capsule ; and finally, to remodel and/or change morphologically in the joint[22]. In this study, the change of condylar position after stabilization splint therapy may be due to the skeleto-dental pattern of the patients.

In comparisons of craniofacial morphology before & after stabilization splint therapy for each malocclusion group by cephalometric records, there were statistical significances: in Class I malocclusion, 3 of 27 measurements(OB, ANB, Wits); in Class II malocclusion, 6 of 27 measurements(OB, OJ, U1APog, LAFH, NSAr, APDI) ; in Class III malocclusion, 12 of 27 measurements(PogNV, OB, OJ, LFH, AC, U1APog, LAFH, SArGo, ArGoMe, SNB, ANB, Wits) ; in Normodivergency, 7 of 27 measurements(OB, MA, LAFH, ArGoMe, PCB:RH, Llip-E, Wits) ; in Hyperdivergency, 12 of 27 measurements(OB, Ulip-E,

LFH, MA, AC, LAFH, SNGoMe, SArGo, FHR, PCB:RH, ANB, APDI) ; in Hypodivergency, 5 of 27 measurements(OB, MA, U1APog, LAFH, APDI) ; in Male, 8 of 27 measurements(OB, OJ, AC, U1APog, LAFH, NSAr, FHR, Wits) ; and in Female, 3 of 27 measurements(OB, Ulip-E, LAFH)(Table 9). Consequently, the effect of stabilization splint was more excellent in Class III, Hyperdivergency, and Male groups. OB only showed statistical significance in all the groups. However, since there are no previous attempts to compare these results, it is considered that the further study will be needed. In all the cases, the mandible was rotated infero-posteriorly after stabilization splint therapy rather compared to that of before stabilization splint therapy.

Roth[20] revealed that the maxillomandibular relationship can be changed as well as the condylar position by stabilization splint therapy. In this study, the maxillomandibular relationships after stabilization splint therapy changed more severely than before stabilization splint therapy. This means stabilizaton splint is very useful in exposing the patient's hidden skeletal problems and evaluating the patient's true malocclusion.

Functional orthodontists have insisted that orthodontic treatment be completed in CRO without any occlusal interference[20,21,22,28,29,33,39]. Functional stability, one of the orthodontic treatment goals, can be accomplished by treating to a stable, reproducible and comfortable CR position. Also, with the increase of medico-legal documentation in our society, orthodontists interested in functional occlusion can avoid and protect themselves from sues by recording condylar position.

To sum up, stabilization splint changes the condylar position into the direction that brings CR and CO closer. It is an useful appliance for displaying the patient's true problems. In other words, since the effect of stabilization splint on craniofacial morphology can be great, orthognathic surgery may be needed rather than orthodontic treatment alone after stabilization splint therapy. Thus, skeleto-dental changes should be forecasted by stabilization splint therapy and the patients should be sufficiently consulted about the changes.

This study will be helpful in orthodontic diagnosis and treatment planning in some degree and further studies on mandibular movement, EMG, and radiographic & animal research to develope functional occlusion concept should be carried out.

CONCLUSIONS

The author evaluated : 1) the normal range of CR-CO discrepancy in normal occlusion group, 2) the changes of condylar position and craniofacial morphology between CR and CO before & after stabilization splint therapy in malocclusion group outside the normal range of CR-CO discrepancy.

The normal occlusion group consisted of 80 subjects who had well-balanced faces and good occlusions with acceptable Class I molar relationship. They had not been treated orthodontically and had no signs or symptoms of temporomandibular joint dysfunction.

71 malocclusion patients enrolled for orthodontic treatment at the Department of Orthodontics, College of Dentistry, Chosun University comprised the malocclusion group, little variation of growth factor by the second molar eruption. They had CR-CO discrepancy beyond normal range and were subdivided into anterior-posteriorly - [25 Class I(0<ANB<4), 22 Class II(ANB ≥ 4), and 24 Class III(ANB ≤ 0)] ; vertically - [20 Normodivergentscy (30<SNGoMe<34), 33 Hyperdivergency(SNGoMe ≥ 34), and 18 Hypodivergency(SNGoMe ≤ 30)] ; and sexually - [26 Male and 45 Female]. For malocclusion group, stabilization splint with mutually protected type of occlusal scheme was applied for three months.

Panadent articulators, Panadent condylar position indicator(CPI), and lateral headfilm were used to investigate the influence of stabilization splint on condylar position and craniofacial morphology.

The results of this study were as follows :

1. The amounts of CR-CO discrepancy in normal occlusion were that the antero-posterior component (△X) was 0.56 ± 0.46mm(Male:0.63 ± 0.42mm, Female:0.49 ± 0.50mm) ; the supero-inferior component(△Y) was -0.75 ± 0.48mm(Male:-0.76 ± 0.52mm, Female : -0.73±0.43mm) ; and the transverse component(△Z) was -0.33 ± 0.28mm(Male : -0.38 ± 0.29mm, Female : -0.31 ± 0.27mm).
2. The condylar position was in normal range after

stabilization splint therapy.

3. The mandible was always rotated infero-posteriorly after stabilization splint therapy.
4. Antero-posteriorly, Class III malocclusion responded very well to the stabilization splint therapy.
5. Vertically, Hyperdivergency responded very well to the stabilization splint therapy.
6. Sexually, Male responded very well to the stabilization splint therapy.

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