DOI: https://doi.org/10.53350/pjmhs22166806

ORIGINAL ARTICLE

Association Between Kinematic Center and Anatomy, The Function of Temporomandibular Joint

ZAHID SARFARAZ KHAN[1], SYEDA GULRUKH SABA SHAH[2], AMBEREEN HUMAYUN[3], ZAKIR ULLAH KHAN[4], WAQAS ALI[5], MAIRA IQBAL[6], NABIHA NAEEM[6], ARSHAD FARID[7], IRFAN ULLAH[6]
[1]Department of Anatomy, Khyber Girls Medical College, Peshawar
[2]Anatomy Department and Modular Coordinator DME, Kabir Medical College, Gandara University, Peshawar
[3]Department of Anatomy, Peshawar Dental College, Riphah International University,
[4] Health Department KPK, Basic Health Unit Moroi (Lower Chitral)
[5]Department of Anatomy, Nowshera Medical College
[6]Department of Life Sciences, School of Science, University of Management and Technology, Lahore, Pakistan
[7]Gomal Center of Biochemistry and Biotechnology, Gomal University, D.I.Khan 29050, Pakistan
Corresponding author: Waqas Ali, Email: drwaqasali123@gmail.com

ABSTRACT
Background: Evident from the literature, the kinematic center (KC) has been proposed as a reference point for representing movements of the TMJ, which includes jaw openings, closings, and protrusions and retrusions.
Objective: The purpose of this study was to determine whether the KC lies in a peculiar anatomical point and whether its trajectory reflects intra-articular distances.
Methods: Dynamic stereo-metry was used to track Four closings and openings and Four protrusions/retrusion in fourteen asymptomatic individuals (8 females and 6 males, ages 21-40).
Results: According to a 3D lattice (0.5 mm grid) constructed solidly around each condyle, the KC had the largest cross-correlation between protrusion-retrusion paths and opening-closing paths. On closing, KC trajectories were more cranial than on opening, consistent with smaller intraarticular distances on closing. Yet KCs never fell on main condylar axes (distance, 4.5 mm) or coincided with points approximating fossa shapes (distance, 12.5 mm).
Conclusion: In this regard, it is unclear what the significance of the kinematic center is anatomically and functionally.

INTRODUCTION
Condylar movement of the temporomandibular joint has been proposed to be represented by the kinematic center (KC), a standard reference point (1) it represent Kinematic Center to lay in middle of condyle spherical, studies found that it is the only condylar point during mandibular movement performing exclusively the movement is translator that will parallel of eminence articular with trajectories supposedly demonstrating the minimal variability. (2)

Given that, the open one is unload in symmetry and the closed one move the opening the trajectories was close toward eminence articular as compared to the close one, it was also thought that the KC trajectories represented variations in intra-articular distances. (3) Additionally, it was discovered that this disparity vanished during loaded opening and closing movements. (4)The primary flaw in all of these studies, as well as those that make use of alternative condylar reference points, is that they don't relate the trajectories to the fossa's shape. Therefore, its looks early for the interfere changes on the distance junction purely by through trajectories of KC as suppose because the anatomic also the function relevance by KC is still unknown. (5)

With the aid of genuine kinematics obtained with six degrees of freedom, the stereometry dynamics enables that 3D re-construction by through TMJ's the animated also the anatomy. (6, 7) As a result, the technique makes it possible to observe the entire condyle moving within the fossa and measure how the true lengths between the surfaces of the condyle and fossa change as movement continues Since the system links the trajectories of the kinematic center duration in many type of movement of the mandibular toward joints of the anatomy, it enables that clarification for the kinematic center's relevance. (8)

Therefore, the purpose of this study was to determine how the KC trajectory and TMJ architecture related to one another. Particularly, asymptomatic people were used to evaluate the following three hypotheses: The kinematic center is located in the condylar center, it is located at the location that best fits the shape of the fossa, and it changes along motions of the unloaded jaw opening and closing that are consistent with the minimum intra-articular distance.

METHODOLOGY
Fourteen participants with asymptomatic TMJ (8 females and 6 males, ages 21 to 40 years) were included in the study. so, the participants of each initially provided history of the medical.

Also, they answered a questions designed for the determine if they currently or in the past have craniomandibular problems.

Those who had no history of CMD had a clinical evaluation to rule out any symptoms. Participants had to move their jaws normally, without pain, and without any palpable tenderness in their TMJ or masticatory muscles in the order to be included in the study. None of the individuals had clicking joints, whereas also existence of painless clicked didn't result in exclusive. All subjects gave their informed consent before participating and were in good overall health.

MRI was used to determine the TMJ architecture for each participant, the motions of jaw was then record as through the individual performing four cycles of symmetric jaw opening and closing and four cycles of symmetric protrusion and retrusion at a controlled rate. Tracking the jaw data through the MRI integration by the help of system reference made up by three spheres of plastic in non-collinear encircled through the liquid contrast of the magnetic in order to recreate and animate genuine Temporomandibular anatomy with its own motion there will be the tracker coordinate system in the jaw, this made it possible to change MRI coordinates. Thus, the 3-dimensional Temporomandibular anatomy might be used to apply the motion data from the jaw-tracking device. Even though the procedure has been extensively discussed elsewhere (9). Here, we'll provide a succinct summary.

The MRI scanning A 1.5 T imaging procedure was carried out while the subject bit down on a custom-occlusal which made the splint that was attach by the bow of the faces that carried the system of the references lateral by through under examination of "TMJ". (10)"take the slice of 12 references and the slices of 14 from every of the long axis TMJ which perpendicular to the condylar spheres of the references centers was established automatical. (11) outlines of the bone of TMJ in manual way was entered for the 3D reconstruction of the joint. After triangulation and polyline contour approximation, a set of cube parametric patches were used to describe the surface.(12) Movements of the mandible were monitored opto-electronically Through the use of splints that did not affect occlusion, two triangle target frames carrying three light-emittion the diode everyone was fastened toward the arches of dental. (12) Three linear cameras captured the positions of the LEDs as they were consecutively pulsed at 70 Hz. A (H) of the maxillary also the (M) mandibular system of the coordination were specified by through TTFs. In relation to "H," the temporospatial alterations of "M" were identified.

Analysis: The primary the axis of condylar, so KC that point of “BA” toward that trajectories most closely resembling the shape of the fossa, also that shortest distance of the intra-articular were all identified. That Jaws-3D standard was followed in choosing the coordinates.

The primary condylar axis was created by joining the centroids of the condylar contours that were the most medial and lateral. Each joint's distance from the kinematic center to the main condylar axis' center was estimated.

Each condyle was surrounded by the three-dimensional work of lattice through the grid of a 0.5-mm that were designed also animate like if it was consider to be connect very roughly with it. The lattice extended minimally the 10 mm in every in direction of spatial. The pathways of every lattice point's the open one and the clos one and with the protrusion and the retrusion was then determined. The point of the lattice works the greatest correspondence among the protrusion-retrusion and opening-closing trajectories was the kinematic center. So That the different in the open also the closed one so the trajectory on that of the direction Z of the caudocranial it will calculate, and the step of the time (t_z) on that differences of the maximum (Z_{max}) were determine. Those lattice points toward a trajector that most closely resembled the shape of the fossa (BA) was the one that maximized the correspondence among the working function that point's trajectory and the fossa's shape. The sagittal MR scans via the main condylar axis' center were used to estimate this form. For each joint, a vector pointing from the KC to the BA was built.

During the opening and closing movements, the centroid by thirty smallest distance among those the fossa and of the condyle was calculated on every step of the time. By linking that centroid of every time of step, we were able for estimate those way for minimal distances intraarticular (h) in middle of the condyle also the fossa as in earlier investigations. As previously explained, the degree of coincidence between the trajectories taken by this centroid when it opened and closed were calculate. Calculated also plot via timing was the position of dorsoventral xh correspond for that very largest different between “h”on open and the close (hmax). “Final also that caudocranially positioning “z” for that Kinematic Center for the each jaw-open ,close cycling was plot via that dorsoventral positioning of the ‘x’ for that Kinematics Center”.

Statistical Analysis: The right joint vectors between the KC and the main condylar axis' center had their mediolateral coordinates inverted because here were not significantly statistical differences of the sides “Wilcoxon tested, $p > 0.05$”. The median distance in middle that Kinematics Center and that point of exact condyl axis’s was measured using data belong to the every joint and the 95 percent of interval confidential that value was calculated. (13)

The associated craniocaudal coordinates XZmax and XHmax, as well as the largest opening and closing path differences Zmax and Hmax, were averaged intra-individually over the observed opening and closing cycles. To investigate whether Zmax and Hmax differed, we used Wilcoxon tests with a 0.05 significance level. The dorso-ventral sites at which these largest disparities occurred were also compared using the same procedure. The coefficient of determination, R2, was then used to determine the strength of the relationship between Zmax and Hmax.

RESULT

In sagittal view, the fossa shape can better be approximated by the trajectory of the KC and the condylar point. That sizes of cube indicates that cross-correlation values between those protrusion-retrusion and opening/closing routes, or the degree of coincidence between the types of that movements is the two (that largest those cubes, which greater that degree by the coincidence.

Only 8 out of the 28 condyles were within the starting locations of the trajectories. The trajectory of the KC and BA are only overlaid at joint no.2; they are somewhat comparable at joints no.8, no.10, and no.12, but very dissimilar at the remaining joints. In light of this, KC trajectories generally deviate from eminence forms. The condyles were never spherical.

The average distances of the KC (d is equal to the 4.1+/- 2.3 mm; Median, 3.9 mm: Range, 0.4-8.4mm) to the point of condyle axis’s (95 percent CI by that Median by d: 2.3-5.3mm). That Kinematic Center was found dorso-cranial in 11 joints (D is equal to the 5.4 +/- 2.1 mm Median, 5.2 mm, Range 1.8-8.4mm), ventrally on 7 joints (D is equal to the 2.7 +/- 1.2 mm Medians 2.3mm, Range 2.2 to 9.9mm), dorso-caudally 4 joints (D is equal to the 3.6 +/- 3.1 mm Median 3.9 mm; Ranges 0.4-6.4mm).

No correspondence was found between BA and the KC. The average distance is 11.6 +/- 5.4mm; Median 12.7mm; Range, 2.5-22.4 mm). In all joints, that mediolateral routes by those mini intraarticular distances with those of open and close. During closing the kinematics center trajectory were much cranial compare to opening (Zmax = -0.8 +/- 0.5 mm; Median 0.7mm Range, -2.2-0.1mm), and the mini intraarticular distances “h’ were significant less during closing than opening (Table-1). The maximal difference for the lowest intraarticular distances (hmax) has a significant correlation with the Kinematics Center trajectory (Zmax) (R2 is equal to the 0.784). That positions for hmax and also the Zmax didn’t line up on that direction of dorsoventral. Instead, hmax occurred before Zmax by 12 to 13 percent (median, 10 percent; range, -9 to 38 percent) of the total excursion.

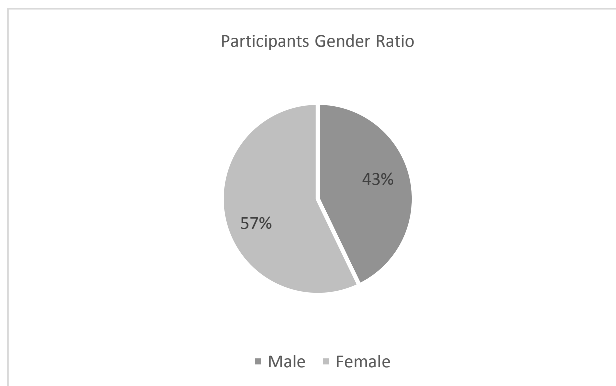

Figure 1: Gender of the participants

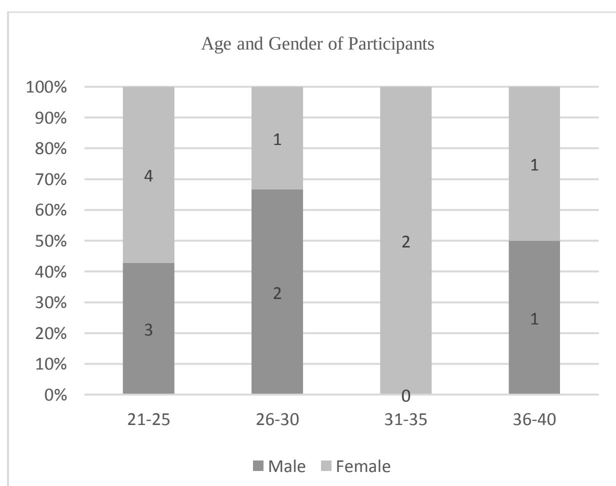

Figure 2: Age and Gender of the Participants

Table-1: Anatomy Of The Condylar And Kinematic-Related Characteriz Data Those Kc With Every Single Tmj

S.No	M/F	Age/Years	TMJ	Sides	Kinematic center			Fossa Point			Close/Open Path		
					x	y	z	x	y	z	Hmax	Zmax	Xmax
1	F	31	1	Left	-8	-8	-9	2	6	-26	0.3	-0.7	38%
			2	Right	-4	-9	-13	-4	-6	-13	-0.2	0.1	17%
2	M	39	3	Left	4	9	2	-5	-7	-3	0.8	-0.6	-3%
			4	Right	-1	-12	-9	-3	3	-10	1.5	-1.5	17%
3	F	29	5	Left	4	-8	6	2	9	2	0.9	-1.1	5%
			6	Right	2	7	-2	-3	-9	-8	0.7	-0.1	2%
4	F	37	7	Left	-14	8	2	-9	3	-8	0.1	-1.1	-9%
			8	Right	-28	10	-3	-26	8	-8	0.1	-0.8	6%
5	M	25	9	Left	-7	-9	1	1	9	-4	0.2	-0.5	25%
			10	Right	-3	7	2	-2	-7	1	0.6	-0.6	19%
6	F	24	11	Left	2	2	2	4	4	-3	1.7	-2.2	18%
			12	Right	2	-6	7	1	-4	2	0.8	-0.9	1%
7	F	21	13	Left	1	4	7	-6	6	-7	0.6	-0.7	13%
			14	Right	-2	-4	-2	-7	-9	2	0.8	-0.9	-6%
8	M	28	15	Left	1	-10	8	2	9	-3	0.8	-0.8	7%
			16	Right	2	-7	3	1	-9	-9	0.5	-0.7	4%
9	F	32	17	Left	2	1	-10	2	-7	-18	0.1	-0.8	4%
			18	Right	2	-12	-9	-4	3	-10	0.6	-0.8	-2%
10	F	25	19	Left	-6	-3	9	-9	9	1	0.9	-0.7	31%
			20	Right	-7	-2	9	-12	-10	14	1.1	-0.9	30%
11	M	23	21	Left	2	8	3	6	7	1	0.8	-0.8	21%
			22	Right	-3	8	9	6	-6	10	0.6	-0.4	16%
12	M	27	23	Left	1	-10	8	2	9	-3	0.8	-0.8	7%
			24	Right	2	-7	3	1	-9	-9	0.5	-0.7	4%
13	F	25	25	Left	-8	-8	-9	2	6	-26	0.3	-0.7	38%
			26	Right	-4	-9	-13	-4	-6	-13	-0.2	0.1	17%
14	M	21	27	Left	2	2	2	4	4	-3	1.7	-2.2	18%
			28	Right	2	-6	7	1	-4	2	0.8	-0.9	1%

“The locations of the kinematic center and the point that comes the closest to the fossa are listed along with their spatial coordinates. In the right three columns, we present: Hmax, or so here is the maxi differences for that of the mini intraarticular distances in middle of that open also that clos phase. Zmax, or those maxi differences by that craniocaudally coordination by the KC way in middle of that open and also the close phase .And XZh, or that distinction between hmax and Zmax's sagittal positions in relation to the sum of their sagittal lengths. Ten cycles are used to average all values”

DISCUSSION

The results of this investigation demonstrated that the kinematic center's position, as described in the literature, unconnected for the anatomy of condylar, with the positions which uncertain (14-17). There is a relationship between the kinematic center and the major condylar axis as well as the point that most closely resembles the shape of the fossa. The dorsoventral coordinated “x” goes by left to right in both illustrations, while the caudocranially coordinated “Z” running from down to the upper. The primary condylar axes have been realigned. (18)

Our study in which the first to demonstrate those kinematic center (Kinematic Center) will even present outside of condyle. had previously noted that the KC was unconnected to the lateral condylar pole. Preliminary data analysis (unpublished) reveals that the degree to which the cranial section of the condyle deviated by the hemisphere which determining that distance between those KC and the condylar axis center: the higher the deviations, of greatening those distances. (19) Those fact that there are such substantial variances in the position of the KC in relation to the condyle is wasn’t surprising to those condyle have intra-individually higher variables—And not ever spherically—shaped. (20)

Additionally, the simplify assumptions toward condyle is a spherically or cylinder that rolls or slides along the fossa ignores the following factors: (1) The existence to the softest compressiblly tissues in middle of the surfaces which is articulates (2) The likelihood that the condyle discs relationships changes when the joint opens and closes; and (3) the different relationship between rotation and translation when the joint opens and closes. In several instances, the KC trajectories even crossed the eminence and were not "parallel" to the fossa. Additionally, the KC trajectory did not generally follow a circular arc. In several instances, they were also in greater cranial positions rather than dorso-caudally near the condylar center as has been hypothesized. These results appear to contradict the idea that the KC attaches to a taut temporomandibular ligament at the condylar connection.

According to reports, the closing trajectory is more caudal during unloaded opening and closing movements than on open. Contrary to this, our findings demonstrated a greater number of cranial closing trajectories, which is associated with that intraarticular distance that have less at closure rather than opened one. For mastication, that was readily demonstrated. Given that we calculated the KC in our study in accordance with its proponents, one explanation for this discrepancy could be that the tracking of the jaw marker weighs more rather the ours “TTFs” do. Ours discovery trough intraarticular distances were lower at closed as compare to the open may indicate the, durination of open, they didn’t elevating the muscles aggressively counteracting it through as firstly caudally directly pulling that suprahyoid muscle, at least in asymptomatic individuals.

Never, Kinematics Center trajectories, like measure on that studies, indirect reflection through variation on that intraarticular distances in middle of jaw open and the close phase, whereas that maxi difference didn’t happen continuously. Because we wanted to capture motions as they happened in a typical environment, we ignored loaded movements in our procedure.

CONCLUSION

This analysis demonstrates that while the traces of the TMJ kinematic center do, in part, reflect the change in spaces of joints, not related with anatomy of the joints when those do not indicate either the movements of the entire condyle or that of surface point.

REFERENCES

1. Gallo L, Gössi D, Colombo V, Palla SJJodr. Relationship between kinematic center and TMJ anatomy and function. 2008;87(8):726-30.
2. Palla S, Gallo L, Gössi DJO, Research C. Dynamic stereometry of the temporomandibular joint. 2003;6:37-47.
3. Tuijt M, Koolstra JH, Lobbezoo F, Naeije MJJob. Differences in loading of the temporomandibular joint during opening and closing of the jaw. 2010;43(6):1048-54.
4. Woodford SC, Robinson DL, Mehl A, Lee PV, Ackland DCJJoB. Measurement of normal and pathological mandibular and temporomandibular joint kinematics: A systematic review. 2020;111:109994.
5. Baeyens J-P, Gilomen H, Erdmann B, Clijsen R, Cabri J, Vissers DJM, et al. In vivo measurement of the 3D kinematics of the temporomandibular joint using miniaturized electromagnetic trackers: technical report. 2013;51(4):479-84.
6. Gallo LMJCTO. Modeling of temporomandibular joint function using MRI and jaw-tracking technologies–mechanics. 2005;180(1):54-68.
7. Scolaro A, Khijmatgar S, Rai PM, Falsarone F, Alicchio F, Mosca A, et al. Efficacy of Kinematic Parameters for Assessment of Temporomandibular Joint Function and Disfunction: A Systematic Review and Meta-Analysis. 2022;9(7):269.
8. Demuynck M, Delnavaz A, Voix JJJoM, Robotics. Human temporomandibular joint motion: A synthesis approach for designing a six-bar kinematic simulator. 2021;13(6).
9. Tuncer A. Kinesiology of the temporomandibular joint. Comparative Kinesiology of the Human Body: Elsevier; 2020. p. 285-302.
10. Gallo L, Colombo V. Functional anatomy and biomechanics of the temporomandibular joint. Contemporary Management of Temporomandibular Disorders: Springer; 2019. p. 71-88.
11. Terhune CE, Mitchell DR, Cooke SB, Kirchhoff CA, Massey JSJTAR. Temporomandibular joint shape in anthropoid primates varies widely and is patterned by size and phylogeny. 2022.
12. Woodford SC, Robinson DL, Edelmann C, Mehl A, Röhrle O, Vee Sin Lee P, et al. Low-profile electromagnetic field sensors in the measurement and modelling of three-dimensional jaw kinematics and occlusal loading. 2021;49(6):1561-71.
13. Zhang S, Zhang Z, Yu W, Ren Y, Ye D, Wang L, et al. Analysis of the correlation between morphology and kinematics of anteriorly displaced TMJ discs using cine-MRI and ARCUSdigma systems. 2018;12(1).
14. Wei F. Behavioral, Functional, and Shape Assessment for Temporomandibular Joint: Clemson University; 2018.
15. Sagl B, Schmid-Schwap M, Piehslinger E, Kundi M, Stavness IJFiP. A dynamic jaw model with a finite-element temporomandibular joint. 2019;10:1156.
16. Wojczyńska A, Gallo L, Bredell M, Leiggener CJIJoO, Surgery M. Alterations of mandibular movement patterns after total joint replacement: a case series of long-term outcomes in patients with total alloplastic temporomandibular joint reconstructions. 2019;48(2):225-32.
17. Ernst M, Schenkenberger AE, Domin M, Kordass B, Lotze MJCOI. Effects of centric mandibular splint therapy on orofacial pain and cerebral activation patterns. 2020;24(6):2005-13.
18. Santana-Mora U, López-Cedrún J, Suárez-Quintanilla J, Varela-Centelles P, Mora MJ, Da Silva JL, et al. Asymmetry of dental or joint anatomy or impaired chewing function contribute to chronic temporomandibular joint disorders. 2021;238:151793.
19. Jurt A, Lee J-Y, Gallo LM, Colombo VJME, Physics. Influence of bolus size and chewing side on temporomandibular joint intra-articular space during mastication. 2020;86:41-6.
20. Linsen SS, Schön A, Mercuri LG, Teschke MJJoO, Surgery M. Unilateral, Alloplastic Temporomandibular Joint Reconstruction, Biomechanically What Happens to the Contralateral Temporomandibular Joint?—A Prospective Cohort Study. 2021;79(10):2016-29.