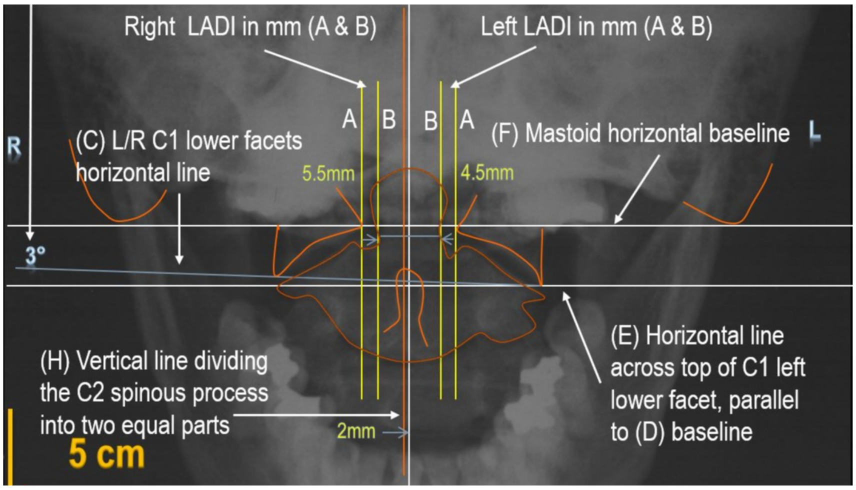

Radiological Improvements in Symmetry of the Lateral Atlantodental Interval and in C1 Tilt After the Application of the Atlasprofilax Method. A Case Series.

Lluis Manent[1], José Gabriel León Higuera, Kathleen Lewis, orlando Angulo, María Emma Zableh Solano[2]

1 Health Sciences University Foundation

2 Universidad Santo Tomás

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Potential competing interests: José G. León: is the medical director of the Atlasprofilax Academy Switzerland Latin America corp. Noemí Laguna: is a former practitioner of the Atlasprofilax method Lluís Manent: is the director of the Atlasprofilax Academy Switzerland Latin America corp. Orlando Angulo: reports no declarations of interest. Kathleen Lewis: is a practitioner of the Atlasprofilax method

Abstract

We present the case of 4 subjects exhibiting asymmetry of the lateral atlantodental interval (within the accepted standard ranges of normal asymmetry) on open mouth x-ray examination. The asymmetry was clearly ameliorated after the Atlasprofilax procedure. Improvements in atlas tilt and axis spinous process deviation also were demonstrated. We discuss the preliminary validity of the Atlasprofilax non-invasive approach for treating such conditions and whether the debate on commonly accepted asymmetry in the lateral atlantodental interval should remain open and be further investigated. We further ask if such a lateral atlantodental interval asymmetry could probably be a pre-manifestation or subclinical pathomechanic condition that could underly some clinical conditions. Asymmetry in lateral atlantodental interval or odontoid-lateral mass interspaces through x-ray examination often has been found in healthy and unhealthy subjects and is associated with atlantoaxial rotatory subluxation. Its clinical relevance remains a controversial subject. Some authors affirm that this asymmetry is a normal variant. Other authors point out that such asymmetry could be considered a manifestation of pathological rotatory conditions of atlas and axis consistent with atlantoaxial rotatory subluxation and possibly lead to musculoskeletal disorders and related chronic pain ailments. X-rays provide information only on bony structures and do not visualize soft tissue structures such as suboccipital muscles and fascia. Therefore, open mouth x-rays alone may not be sufficient to determine a radiological pathological condition specially one that is not yet presenting clinical symptoms because soft tissue alterations in this region are not visualized on x-ray. Several x-ray protocols and studies have been performed on this craniocervical segment with different results and interpretations. In this case series, we examine changes in the asymmetry of the lateral atlantodental interval, atlas vertebra tilt and axis spinous process deviation before and after application of the Atlasprofilax method in four patients. This method focuses on mechanotransduction through vibropressure on soft structures of the craniocervical joint, targeting deep cervical fascia, suboccipital muscles and cartilage. The aim is to restore normal structural and metabolic patterns in the extracellular matrix. This also would imply changes in chondrocytes, telocytes, and fibroblasts through a piezoresistive effect. This effect could lead to amelioration of connective tissue alterations in the craniocervical junction involving collagen synthesis, hyaluronic acid and abnormal patterns in fibroblasts and in the microvacuolar fascia. These changes ultimately could result in an improvement in the lateral atlantodental interval and craniocervical joint position.

Authors' contributions

José G. León: Conceptualization, Supervision; **Noemí Laguna**: Investigation, Methodology, Materials and Methods; **Lluís Manent:** Writing - original draft, review & editing, supervision; **Kathleen Lewis:** supervision, editing & review. **Orlando Angulo Ceballos:** supervision, review.

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Consent

Written informed consent from all participant subjects was obtained.

Human and animal rights

As an observational case report, no experiments were performed on human subjects. Nevertheless, this case study is within the ethical standards of the Helsinki Declaration of 1975, as revised in 2000.

Keywords

Atlantoaxial rotatory subluxation; Lateral atlantodental interval; Odontoid-lateral mass interspaces asymmetry; Atlasprofilax; Mechanotransduction; Craniocervical joint; C1 tilt, Vertebral Subluxation Complex, Vertebral subluxation.

CASE SERIES

Methods, measurements, intervention and endpoints

Methods

Four randomly selected patients -three female and one male- participated in the case study. Each subject underwent standing open-mouth C1-C2 x-ray examination, according the guidelines specified by Murphy (1), with collimation on all four sides up to the region to be explored, approximately 10cm x 10cm. The collimation ray was established perpendicular to the chassis anddirected to the center of the open mouth. DFP: 100cm. Plate 18x24.

The patients then were asked to hold their breath and keep the tongue close to the lower jaw to allow visualization of the odontoid process and the C1-C2 vertebrae. The position was erect, with the arms at the sides and the head resting on the surface of the table. The midsagittal plane was aligned with the collimation ray and the midline of the table. The mouth was open, so that a line could be drawn across the inferior points of the mastoid processes -similar to the vertices of two parabolas.

The same radiological equipment and technique were used before the Atlasprofilax method and one month after the treatment on each subject to compare differences in the lateral atlantodental interval (LADI), atlas tilt and C2 spinous process deviation pre- and post-application of the Atlasprofilax method. The measurements were performed by a radiologist.

Measurements

Determining LADI:

A vertical line was drawn at the medial point of each lateral mass of the atlas (A) where the lateral mass was in closest proximity to the odontoid. Another vertical line was drawn at the at the odontoid neck (B). (See figure 1). Due to the anatomical variations in the shape of the odontoid process, which generally occur in its upper two thirds, the space to be measured between the inner edge of the lateral mass and the outer edge of the odontoid process is the one located at the neck of the odontoid process, i.e. the one located just on the line joining the narrowest edges of both lateral masses.

Determining C1 tilt:

A line was drawn from one C1 lower facet to the contralateral lower facet (C) to establish possible tilt in degrees relative to a previously established main horizontal baseline (D). A horizontal baseline parallel to the main baseline contacting the first lower facet of C1 was drawn (E). Another baseline was drawn across the inferior edge of the mastoid processes (F) to compare C1 tilt from the base line and to avoid possible bias due to head tilting (See figure 1).

Determining C2 spinous process deviation:

A vertical dividing line was drawn dividing the odontoid into two equal parts (G). Another vertical dividing line was drawn dividing the spinous process of C2 in two (H) to measure deviations from the first vertical line dividing the odontoid. (See figure 1).

Intervention

The intervention consisted of a non-invasive neurostimulation to several key points of the suboccipital area to stimulate certain muscle and fascial receptors. The device used controlled percussion vibropressure at specific frequency which was applied for eight minutes. The intent was to achieve a deep mechanotransduction effect on the suboccipital muscles which regulate C1-C2 position and head movement (2).

Endpoints

The endpoints were established based on radiological comparison before and after the intervention as follows:

LADI: Increased left/right symmetry of the LADI (A and B) between the vertical lines of each atlas' lateral mass and its proximity to the odontoid measured in millimeters. See figure 1.

C1 tilt: Determination of the improvement in the tilt angle, measured in degrees, between the horizontal baseline (D) and another line joining the lower articular facets of C1 (C and E) by subtracting the possible head tilt that was measured with another baseline drawn between the inferior edge of both mastoid processes (F). See figure 1.

C2 spinous process deviation: A vertical line dividing equal parts of the odontoid (G) was established and its alignment or deviation was compared with respect to another vertical line in the center of the spinous process of C2 (H) to determine a better alignment post-intervention. See figure 1.

Results

The LADI's average degree of left vs right (a)symmetry was 1.25 mm before the intervention and 0.5 mm after the intervention for all patients. Thus, average LADI asymmetry was reduced by 2.5-fold. See table 1.

The average degree of tilt of C1 was 1.75º before the intervention 0.75º after the intervention. See table 1.

The average deviation of the C2 spinous process was 3.5 mm before the intervention and 2,5 mm after the intervention. See table 1.

Subject 1 achieved perfect symmetry in LADI, C1 tilt and C2 spinous process, as seen in the comparative figure 2. Head tilt bias of C1 was avoided by establishing the aforementioned main base line (D), a mastoid horizontal baseline (F) and a first contacting C1's lower facet equal to the horizontal main baseline (E) where subtracting 4º of mastoid tilt from 4º of atlas tilt gave 0º head tilt during the x-ray procedure. See figure 2.

As with subject 1, subjects 3 and 4 achieved total LADI symmetry after the therapy. Their pre-treatment LADI difference (L/R) was 1mm in subjects 1 and 4 and 2mm in subject 3, an asymmetry which is considered within the normal LADI's asymmetry ranges according to another study in 230 Chinese patients, where the normal range of asymmetry was determined to go from 0.1 to 2mm (3). Interestingly, previous LADI's asymmetry in these three patients was completely normalized achieving 100% of left/right post-therapy symmetry, challenging if there is room for improvement in what is usually considered as normal asymmetry. That was not the case with subject 2, who underwent an increase of 1 mm of LADI asymmetry but the C2 spinous process deviation was reduced by 2 mm and there was no C1 tilt before and after the therapy. C2 spinous process deviation was completely corrected in subject 1 and partially ameliorated in subjects 2 and 3 while in subject 4 it was moderately increased by 0.5 mm, whereas previous C1 tilt was eliminated in subject 1, ameliorated in subject 4 and remained the same in subjects 2 and 3. See table 1.

DISCUSSION

Asymmetry of the odontoid-lateral mass interspaces: a controversial issue

Odontoid-lateral mass interspace asymmetry is a divisive and controversial issue among radiologists (4–7). Also known as lateral atlantodental interval (LADI), it commonly is measured with open mouth transoral x-ray, and also used to determine atlantoaxial rotatory subluxation (ARS). When executing radiological measurements for LADI or ARS, neutral head position is very important in order to avoid bias and false positive results (8). While some specialists think that this asymmetry can be categorized as a normal variant (3), others consider it a sign for a pathological rotatory condition of C1-C2 consistent with ARS. Traumatic atlantoaxial injury has been associated with ARS (9), but radiographic evidence with ARS in patients without clinical manifestations has also been found, raising the question of the accuracy and relevance of radiological diagnosis in this matter. In one study, patients with ARS who were manually treated did not show improvement in C1 rotational position, leading to the conclusion that this radiographic finding of odontoid-lateral mass interspaces asymmetry or LADI is common and not an abnormal condition (4). In pediatric patients, several clinical manifestations associated with injury and ARS were found when compared to patients who did not present with ARS (10), but LADI in differences in both groups appeared to be insignificant (11). Open mouth transoral x-ray examination is considered adequate to diagnose ARS whereas MRI is not considered to be useful (12). In one study, 54% of non-injured patients presented with asymmetry in the odontoid-lateral mass interspaces on anteroposterior open-mouth x-ray examination (4), leading to a preliminary conclusion that odontoid-lateral mass interspaces asymmetry seems to be a normal variant in non-injured/non ARS patients. But the craniocervical junction (CCJ) consists of many soft tissue structures, including mechanorreceptors and nociceptors. Thus, the question is left open as to whether diagnosing ARS diagnosing through open mouth x-rays is sufficient for determining a currently subclinical radiological pathological condition when possible surrounding soft tissue alterations in this region cannot be seen. Other researchers who found significant asymmetries at the atlanto-axial segment assert that such findings may imply relevant signs for dysfunction and disorders (13). An atlas-adjustment treatment was developed by Dr. William G. Blair who relied on thousands of stereoscopic radiographs and cadaver dissections in which a high number of asymmetries in CCJ's structures was found (14).

The craniocervical junction and the vertebral subluxation complex

Along with bones (C0-C1-C2), ligaments, muscles, and fascia along with their nervous and vascular structures form the craniocervical junction (CCJ). Together they form a functional unit.

The Vertebral Subluxation Complex (VSC) concept was established and developed in the 17th and 18th centuries (15) (16) being defined as "*a dislocation or putting out of joynt*". Chiropractic and allopathic medicine have studied this phenomenon with relatively different approaches suggesting often that it can have clinical and biological relevance (17,18). Both disciplines have performed studies on this subject, including radiological studies (14,19–22) and settling several treatments to fix this misalignment (23,24).

Even if some chiropractors put the focus on VSC, pointing out its implications in pain and disability, there still is no clear consensus among chiropractors (25,26) or physicians on this matter. This is due partially to the different definitions chiropractic and medicine give to a vertebral subluxation (27,28).

Even the World Health Organization differentiates the definition of a chiropractic vertebral subluxation from a medical vertebral subluxation (29). .

However, this issue is addressed today through a variety of osteopathic, physiotherapeutic, myofascial and chiropractic treatments for the upper cervical region including the CCJ (30), stating that ARS and rotatory CCJ dysfunction should be treated and addressed as a real condition and issue of relevance for human health (31).

A non-invasive method called Atlasprofilax has been developed and is being applied in some hospitals and clinics in Latin America to treat clinical and subclinical CCJ minor disarrangements/ARS from a less bony and more fascial and soft tissue approach, targeting especially deep cervical fascia, suboccipital muscles and the myodural bridge (MBD).

Suboccipital fascial structures have biomechanical and physiological correlations with the dorsal meningovertebral ligament of the atlas and axis at atlantoaxial interspace level (32). The posterior surface of the dura mater, rich in elastin fiber content (33) and in proprioceptive neurons (34), is interlinked with these structures. It cannot be excluded that a mechanical wave and vibropressure application may have a mechanotransduction effect on soft structures such as the myodural bridge, the suboccipital fascia and certain ligaments, allowing a mechanical optimization of asymmetries present in hard bony structures such as the atlanto-odontoid space.

Two previous studies on the beneficial effects of the Atlasprofilax method in 63 patients with fibromyalgia (35) and in 151 with temporomandibular disorders (36) showed considerable long-term efficacy. LADI and ARS normalization after the Atlasprofilax treatment intervention was reported in another case report (37) along with clinical improvement in patient ailments. This might suggest that the clinical implications of the CCJ complex and of probable abnormalities in the deep cervical fascia and in the suboccipital muscles have a greater relevance in these pathologies and most likely in several others as well -all of which have been underestimated to date. Because the fascia is a continuum (38) any abnormality in suboccipital muscles and fascial structures could create biomechanical and fascial descending alterations with a probable myofascial and articular imbalance in other regions such as the lumbar being a cofactor that could predispose, for example, the alteration of intervertebral discs (39).

The Atlasprofilax method uses a device that generates controlled vibropressure at specific frequencies, stimulating neuromuscular and myofascial structures to induce positive changes at a cellular and molecular level, leading to a restoration of the extracellular matrix (ECM). Changes in cell behavior as a result of mechanical stress have been reported in the literature. Those changes do include a variety of chemical, electrical and metabolic reactions affecting cell membranes, microtubules and other parts of the cytoskeleton through a complex combination of reactions and interactions (40). The Atlasprofilax method uses mechanotransduction principles (41–43) in the interlinked relationship between mechanical forces, biochemical signals, and metabolic information as well as electrical and hormonal signaling mechanisms. As we have seen, ARS and asymmetrical LADI are present in injured as well in non-injured subjects independently if those patients present clinical manifestations such as neck pain or tensional headache among others. But x-ray examination of ARS/LADI only reveals information on hard structures such as bones and joints, and therefore is unable to evaluate the histological conformation of important CCJ structures such as fascia, suboccipital muscles, tendons and ligaments. Since these soft structures can be affected without demonstrating clinical signs, especially in the early stages these soft tissue changes should be confirmed by using MRI-Diffusion tensor imaging techniques.

Thus, by applying dynamic forces with the Atlasprofilax technique through deep friction vibropressure including shear-stress, compression, different frequency rates, and tension, specific mechanical stimuli are applied to fascia, muscles and cartilage. The stimuli are absorbed into the ECM, and are subsequently transmitted to chondrocytes, telocytes, and fibroblasts, in an effort to restore interstitial biochemical and metabolic processes. The goal is to positively affect connective tissue alterations that involve collagen, hyaluronic acid and the microvacuolar fascia, targeting an amelioration of collagen synthesis and abnormal fibrotic patterns. Some cells such as telocytes are responsible for gap junction, allowing correct passage of molecules and ion between cells. This can lead to an improvement in the deep cervical fascia as well as in the suboccipital muscles (rectus capitis minor and major; obliquus superior and inferior) and in the related ligaments that maintain C1 and C2 in an ideal position. As a result, an improvement in ARS and LADI in symptomatic and asymptomatic patients can occur. If such a positive stimulus offered by the Atlasprofilax method in symptomatic/asymptomatic patients is applied, an improvement in subclinical ARS and LADI asymmetry could be expected. In this small case series, we preliminary establish if such improvement can be achieved.
The results in this small group of patients show radiological evidence of significant changes in the LADI asymmetries, C1 tilt and C2 misalignment after the application of the Atlasprofilax method.

The results could suggest that the accepted range of asymmetry of the LADI currently accepted as normal in healthy individuals could be improved with such a therapeutic approach. These results therefore preliminarily indicate that minor LADI asymmetry could be a subclinical pathomechanic condition that could lead later to clinical symptoms and ailments. It is also possible that even minor LADI asymmetries could be indicators for certain pathologies related to the upper cervical spine. This will be further elucidated by another cross-sectional observational study with a much bigger sample.
These results, although preliminary and with a very small representative sample, add material to the well-known discussion on whether asymmetry of the atlantodental interspaces is a normal variant or if it should be considered a pathology or a clinical/subclinical manifestation of relevance. The Atlasprofilax method focuses on restoration through mechanotransduction of the suboccipital muscles that position the atlas and axis in the CCJ complex being a soft tissue

approach and a non-direct manipulative chiropractic or osteopathic approach. The role, clinical implications and likely pathophysiology of the soft structures of this segment that could alter the position of CCJ's hard structures remain to be elucidated. But the radiological improvement in the asymmetries of these bony and articular structures should most likely be subsequent to metabolic changes of suboccipital muscles and other fascial structures that give tensegrity to the CCJ segment. This is a preliminary case series study of an ongoing study for future publication with a much larger cohort towards verification of the trend observed in this case study.

TEACHING POINT

The discussion on the relevance of LADI and ARS in symptomatic and asymptomatic patients and its clinical implications remains open. More radiological and clinical data are needed on the possible benefit that the Atlasprofilax method could have in pathologies commonly associated with upper cervical musculoskeletal disorders, including, but not limited to, chronic tension headache, cervicobrachialgia and chronic cervicalgia among others.

TABLES

Table 1. LADI, C1 tilt and C2 spinous process deviation before and after the application of the Atlasprofilax Method.

Subject		LADI Right (in mm)	LADI Left (in mm)	LADI Left vs. Right difference (absolute value in mm)	C1 tilt in degrees	C2 deviation of spinous process (in mm
Subject 1	Before	5.5	4.5	1.0	3º	2.0
	After	6.5	6.5	0.0	0º	0.0
Subject 2	Before	11.5	10.5	1.0	0º	7.0
	After	7.5	9.5	2.0	0º	5.0
Subject 3	Before	3.5	5.5	2.0	2º	4.0
	After	7.5	7.5	0.0	2º	3.5
Subject 4	Before	6.5	5.0	1.0	2º	1.0
	After	6.5	6.5	0.0	1º	1.5
Average difference for all patients	**Before**	**---**	**---**	**1.25**	**1.75º**	**3.5**
	After	**---**	**---**	**0.5**	**0.75º**	**2.5**

FIGURES

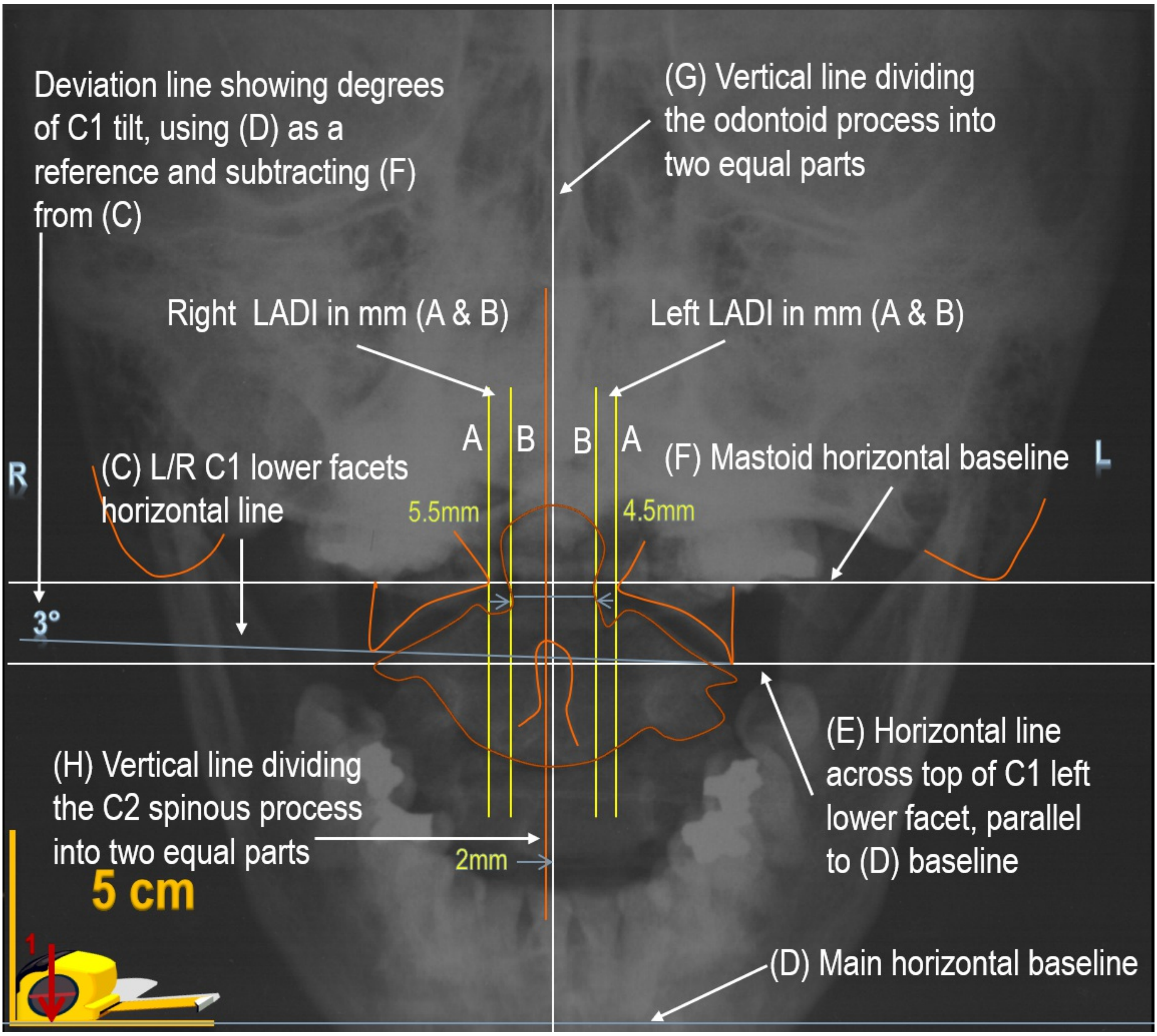

Figure 1: Lines drawn to determine LADI ((A) & (B)), C1 tilt (lines (C), (D), (E), & (F)) and C2 spinous process deviation ((G) & (H))

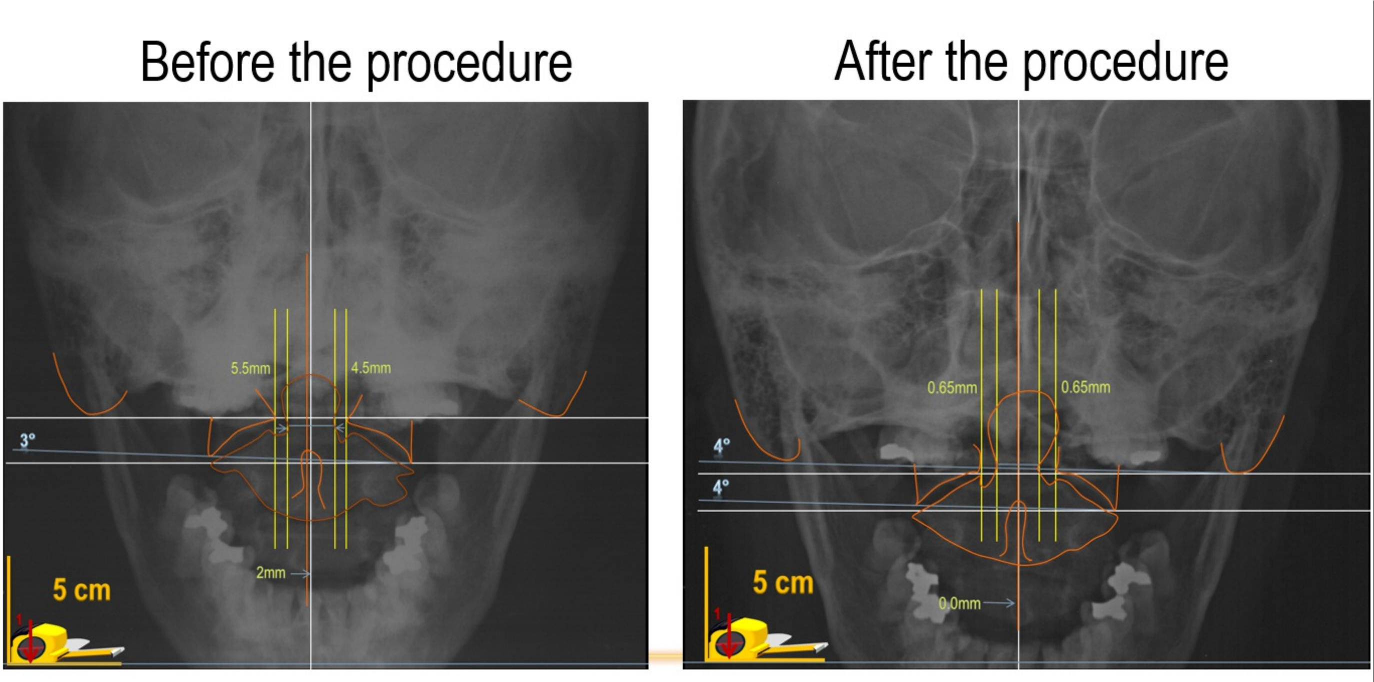

FIGURE 2: Total LADI symmetry of Subject 1 after application of the Atlasprofilax method, with eradication of both C1 tilt and C2 spinous process deviation.

ABBREVIATIONS

ARS = Atlantoaxial rotatory subluxation

CCJ = Craniocervical junction

ECM = Extracellular matrix

LADI = Lateral atlantodental interval

MRI-DTI = Diffusion tensor imaging tractography by magnetic resonance

VSC = Vertebral Subluxation Complex

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