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Muscular activity during isometric incisal biting

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ABSTRACT

This study attempted to estimate TMJ loading during incisal loading using a custom load-cell device and surface electromyographic (*s*EMG) recordings of the main jaw closers to assess the outcome correlation. Study participants were 23 healthy volunteers. The incisal loads having submaximal and mean intensity were recorded using a calibrated electronic load cell; simultaneously, surface electromyography (*s*EMG) of the right and left masseter and temporalis muscles was recorded. Readings of the resting, clenching in maximal and submaximal intercuspal positions and mean (50%) incisal loads were recorded. Clenching *s*EMG activity was used as a reference for normalization. The mean (SD) submaximal incisal load recorded was 498 (305.78) N, and the mean at 50% of the submaximal load was 268.93 (147.37) N. Mean (SD) *s*EMG activity during submaximal clenching was 141.23 (87.76) μV, with no significant differences between the four muscles. During submaximal voluntary incisal loading, the normalized mean *s*EMG activity was 49.99 (34.54) μV %, and 27.17(15.29) μV % during mean (50%) effort. The incisal load was generated mainly by the masseter muscles, as these showed a positive correlation during mean but not during submaximal effort. In the edge-to-edge jaw position, the mean incisal load effort seems to be physiological, but excessive TMJ loads can be expected from chronic or excessive incisal loading. In conclusion, incisal loads require the activity of the masseter muscles, which show a positive correlation between *s*EMG activity and effective incisal loads during mean, but not during submaximal, effort, and the masseter muscles are dominant over the temporalis muscles during submaximal incisal biting.

1. Background

Temporomandibular joint (TMJ) disorders (TMD) are considered to be unexplained clinical conditions (Aaron and Buchwald, 2001); pain and limited jaw opening are the main symptoms. The factors that cause TMD are still unknown (De Leeuw and Klasser, 2013), although loading is considered the main underlying factor (Tanaka et al., 2008), and the masseter muscles exert the main loads on the TMJ (Koolstra et al., 1988; Hannam and McMillan, 1994). The activity of these muscles is influenced more by the position and magnitude of occlusal forces than by TMJ loads (Throckmorton et al., 1990). Forces generated by the masticatory muscles are influenced by neural factors transmitted by the Golgi tendon organs which are highly sensitive tension receptors, and by the periodontal ligament (Bakke et al., 1992) but the TMJ's mechano-receptors also play a part in preventing oromandibular damage from excessive loading (Erkelens and Bosman, 1985; Sowman and Türker, 2008).

Ethical concerns make it impossible to directly measure TMJ loading in humans because the TMJ is a very inaccessible joint and the insertion of measuring equipment such as pressure-sensitive devices would involve major disruption for the patient and as well as modifying the biological environment of the joint. Experimental studies in animals have shown that the TMJ is a stress-bearing joint (Hylander, 1997); this conclusion was supported by a later study by Brehnan et al. (1981), who recorded greater loading of the TMJ for incisal (3–4 lb) than for molar (1–3 lb) biting at the condyle in a macaque (*Macaca arctoides*). Finite element analysis has suggested that forces generated during incisal biting increase TMJ loading (del Palomar et al., 2008).

During incisal biting, no muscles are in a position to distract the condyles, and consequently all elevator muscles combine to direct the condyles in an antero-superior direction in centric relation and also to keep them loaded against the eminentiae (Tanaka et al., 1994; Korioth and Hannam, 1994; Hannam and McMillan, 1994; Dawson, 1995; Farella et al., 2008).

The muscle co-activation determines the magnitudes and directions of TMJ loads (Throckmorton et al., 1990; Tanaka et al., 1994; Trainor et al., 1995; Nickel et al., 2012). Little information is available about the specific contribution of each muscle; for instance, a 1:1 ratio

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has been reported for the temporalis and masseter muscles during isometric incisal biting, but a ratio closer to 3:1 between the surface electromyography (*s*EMG) magnitude of the pair of triple masseters (182 μV) to the temporalis (69 μV) during mean—30 to 60% of maximal—incisal effort (Throckmorton et al., 1990).

The specific contribution of each individual muscle force to the total incisal bite forces and resultant TMJ loads is unknown. The proportion contributed by each muscle seems to differ depending on the tooth position when biting (Throckmorton et al., 1990) and also on the magnitude of the generated loads (Sowman and Türker, 2008).

We speculate that if during isometric incisal biting the activity of the temporalis pair predominates, then the TMJ remains "protected" against overloading; however, if the masseter (perpendicular to the eminentiae) muscles predominate, an increase in TMJ loading should be expected. Moreover, we assume that generating muscular forces requires their activation and that this activation can be recorded by *s*EMG. These *s*EMG recordings showed linear relationships with generated occlusal loads on a short-term basis (Ferrario et al., 2004). Thus, although *s*EMG data do not match occlusal forces, *s*EMG magnitude can indirectly predict, with linear relationships on a short-term basis, the effective magnitude of occlusal loads generated by jaw-muscles. Based on jaw-biodynamics during incisal biting, in which the jaw seems to act as a class III lever with three points (the incisal point as the effort arm and two TMJ points as the resistance arms with the muscular elevator point between them, but nearest to the TMJ points), and on model predictions (Tanaka et al., 1994; Korioth and Hannam, 1994; del Palomar et al., 2008), TMJ-loads could indirectly and reasonably be inferred, although they have not been measured in this study.

In this study, we attempted to investigate the *s*EMG activity of jaw closers during symmetric incisal biting and their linearity with generated loads at the incisal level. The study hypothesis was that incisal force intensity increases when *s*EMG activity of the jaw elevators increases; moreover, there are no differences in *s*EMG

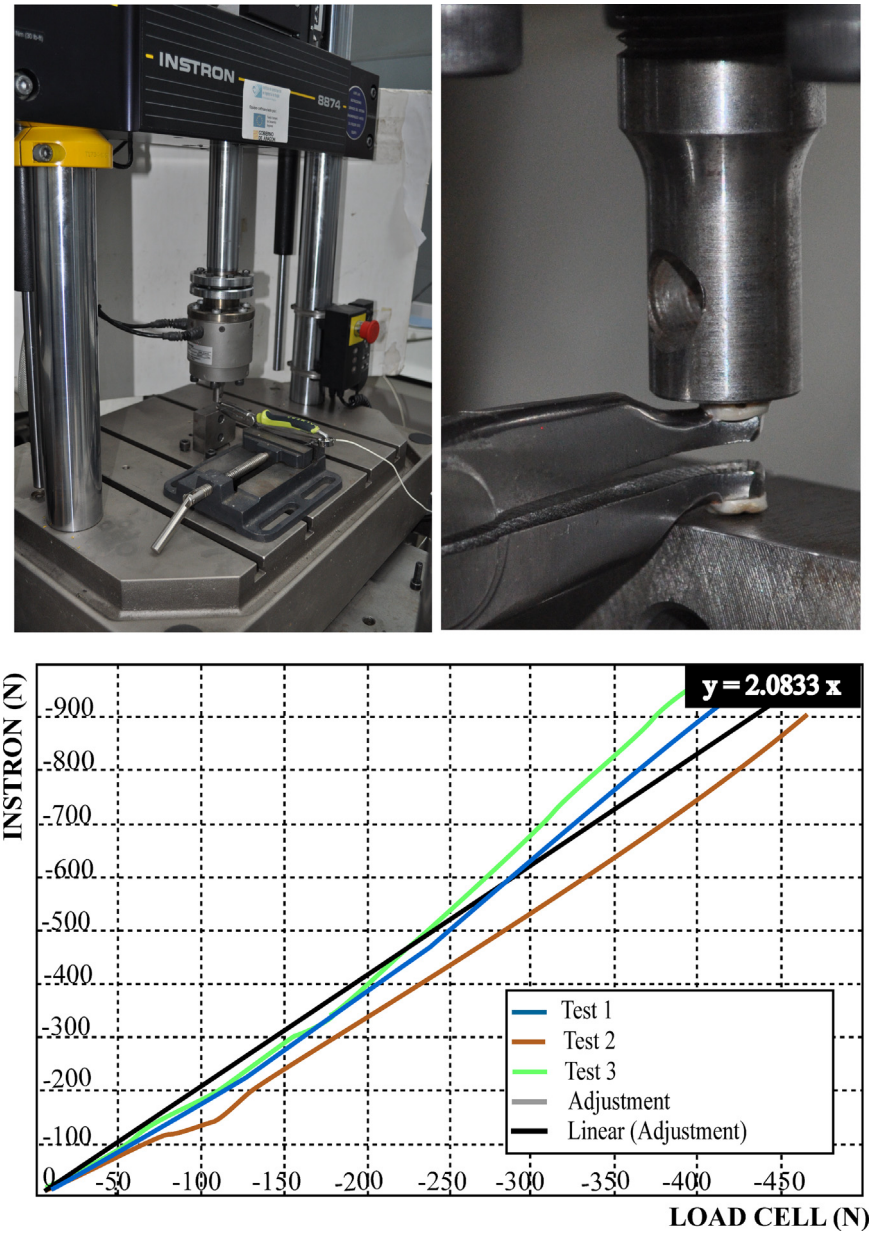

Fig. 1. Upper panel: The experimental setup used to calibrate the custom load cell in a universal testing machine. Lower panel: The resultant graph used to obtain the transformation coefficient "*y*".