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# An appliance designed for experimental mandibular hyperpropulsion in rats

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SUMMARY Many animal experiments dealing with function–form interaction and mandibular condylar growth have utilized hyperpropulsion of the animal's mandible. Numerous hyperpropulsive appliances have been described in the literature. However, there are significant discrepancies between reported results which are most likely due to the use of appliances that do not secure true mandibular hyperpropulsion.The specific rat craniofacial anatomy as well as the masticatory physiology of this animal requires the design of a specific appliance that would meet the species' functional characteristics.

The aim of this paper is to describe a new type of appliance that can produce a controlled, stable and reproducible anterior displacement of the mandible in rats. After reviewing and evaluating the appliances used by other researchers, a totally new appliance for experimental mandibular hyperpropulsion in rats is presented. Its advantages are: (i) it produces a secure, measurable and reproducible anterior displacement of the mandible; (ii) it does not permit any retrusive or lateral mandibular movements. Avoidance of this variable can increase reliability of results and minimize involvement of other confusing parameters; and (iii) it allows the animals to be fed sufficiently for a number of hours every day. The appliance consists of an acrylic collar brace fitted to the animal's neck and carrying wire extensions that support rubber bands pulling on a band cemented to the animal's lower incisors. The pulling force depends on the thickness of the applied elastics.

## Introduction

Several animal experimental studies of mandibular anterior displacement have been performed in order to evaluate the role of functional factors as well as the role of the condylar cartilage in mandibular growth. It has been demonstrated that consistent morphological changes can be produced in non-human primates that have been submitted to forced mandibular hyperpropulsion (Baume and Derichsweiler, 1961; Joho, 1968; Stöckli and Willert, 1971; Adams *et al.*, 1972; McNamara, 1973). On the other hand, significant discrepancies have been reported in experiments dealing with mandibular hyperpropulsion in rats (Petrovic *et al.*, 1975; Tonge *et al.*, 1982; Ghafari and Degroote, 1986; Tewson *etal.*, 1988); one possible reason could be the lack of effective application of functional appliances to achieve reproducible and comparable situations.

Experimental studies that use animal models can eliminate many of the variables of clinical studies which can often affect the reliability of the research findings. On the other hand, animal studies that use forced changes in the mandibular position may have severe problems of reliability due to impairment of the animal's feeding ability. Other problems include consistency of the achieved mandibular position through the use of the various hyperpropulsive appliances. These conditions are greatly affected by the appropriate design and fit of the experimental appliances. The specific rat craniofacial anatomy as well as the animal's masticatory physiology (Hiiemae and Ardran, 1968; Weijs, 1973; Siegel and Mooney, 1990) require the design of an

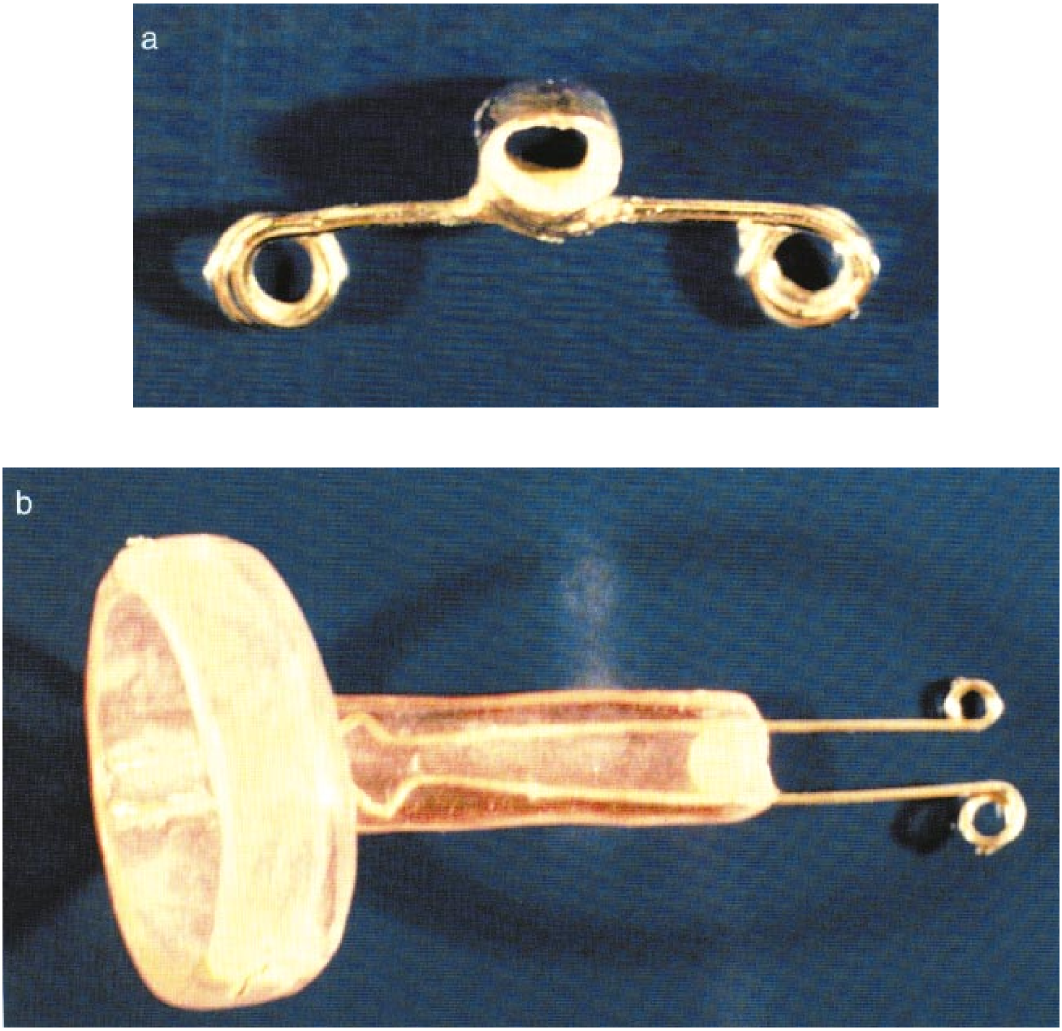


**Figure 1** (a) Intraoral part of the appliance. The band is cemented to the lower incisors of the animal. (b) Extraoral part of the appliance. The necklace portion is split in two halves for easy removal and repositioning around the animal's neck.

appliance that will respect the species' functional requirements and thus lead to a more consistent and reproducible mandibular position, and hence to more valid results.

In order to initiate rat hyperpropulsive experiments, the authors began a search for an appliance that could produce a definite and controlled anterior displacement of the mandible and reviewed the various types of experimental appliances previously described in the literature. These appliances have been used in the past for similar purposes by Petrovic *et al.* (1975), Tonge *et al.* (1982), Ghafari and Degroote (1986) and Tewson *et al.* (1988). Taking into consideration the drawbacks of the previous appliances which will be discussed later, an appliance that met the above-mentioned requirements was designed in order to produce a controlled, stable and reproducible anterior displacement of the mandible without endangering the animal's survival. The aim of this paper is to describe this appliance and discuss its effectiveness.

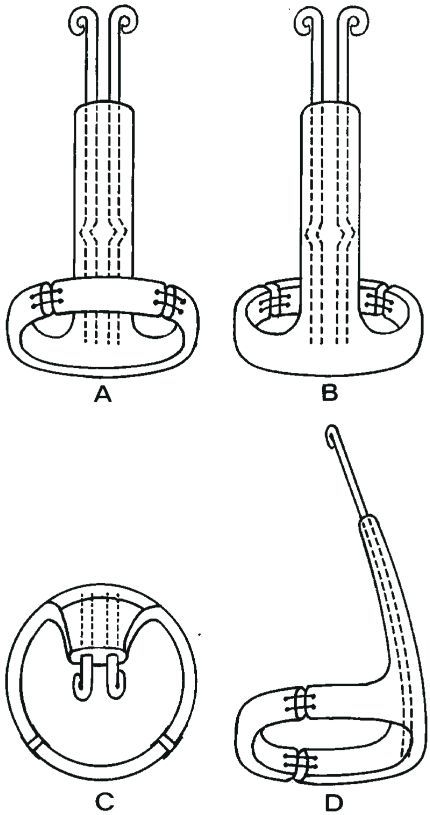


**Figure 2** Diagrammatic presentation of various views of the extraoral part of the appliance. (A) Ventral; (B) dorsal; (C) frontal; (D) lateral.

### Description of the appliance designed to cause experimental anterior displacement of the mandible in rats

The appliance was composed of intra- and extra-oral parts as follows (Figures 1a, b and 2).

1. The intraoral part consisted of a specially constructed stainless steel band which surrounded the lower incisors of the rat. Xantopren/Optosil impressions of the mandibular arch of the animal were taken with custom-made acrylic trays previously constructed using mandibles from dry rat skulls at comparable ages. The impression was poured in Velmix Stone and the intraoral band of the lower incisors was constructed on the resulting cast. On the labial surface of this metal band a heavy wire bar (0. 050 inches in diameter) (Figure 1a) was soldered at an angle of 90 degrees to the long axis of the incisors. The wire was 1 cm long and ended in two rounded loops. These can be used for attachment of rubber bands.
2. The extraoral part of the appliance was constructed from cold cured acrylic resin on a utility wax mould the size of the rat's neck. It was in the form of a ring, approximately 3 mm wide with a flat extension on the top. The ring was made to fit like a loose necklace around the animal's neck with the flat acrylic extension placed on top of the animal's head and extending forward approximately 2–3 cm. On the dorsal surface of the acrylic covering the animal's head, two heavy wires (0.050 inches in diameter) (Figures 1b and 2) wereembedded and directed horizontally approximately 3 mm forward to the most anterior point of the animal's upper incisors. The edges of the two wires were bent so that they formed two rounded loops on which rubber bands could be attached. The acrylic necklace was divided in two halves in two respective positions, which corresponded to the sides of the animal's neck. Then, on each half, two matched holes were drilled, which were used to put the appliance back together by means of ligation. By cutting and replacing these wire ligatures, the appliance could be opened, removed and replaced around the animal's neck without any pressure or trauma to the underlying soft tissues (Figure 2).
3. Two rubber bands were applied in a Class II fashion from the loops of the wire soldered on the intraoral band to the loops of the wires embedded in the acrylic of the head extension of the extraoral element (Figure 3). These rubber bands were selected to exert a pulling force of approximately 25 g per side and the mandible was thus brought to a straight, forward propulsion to such an extent as to produce an obvious anterior crossbite of the incisors. Depending on the experimental protocol, feeding of the animal could be accomplished by removing the extraoral

**Figure 3** Necklace and wire extensions over the animal's head. Rubber bands are also applied.

portion of the appliance for a number of hours each day. It could then be repositioned by means of the wire ligatures without any injury or discomfort to the animal.

The hyperpropulsive effect of the appliance was examined, and checked clinically and radiographically (Figure 4).

### Effects of experiment on the weight of the animals

Twenty-four 4-week-old male Wistar rats were used in this study. The animals used were obtained from the Greek Pasteur Center. The initial weight of the animals ranged from 41 to 44 g. The animals were divided into two different groups, one control (group B) and one experimental (group A), each consisting of 12 animals. The experimental group (group A) included 12 rats in which the mandible was forced to function in a protracted position by application of the hyperpropulsive appliance.

The animals were weighed at the beginning of the experiment (Table 1) and every third day thereafter. The final body weight was determined immediately prior to killing (Table 1). The *t*-test between groups A and B showed significant differences, but the animals in group A (experimental) grew and functioned normally and their weights were within the normal range for their age (Donta, 1981).

## Discussion

Appliances causing forced anterior displacement of the rat mandible have been used by several researchers in the past, in experiments with rats (Petrovic *et al.*, 1975; Tonge *et al.*, 1982; Ghafari and Degroote, 1986; Tewson *et al.*, 1988) as well as monkeys (McNamara, 1981). Anterior jaw displacement in monkeys is relatively easy and is accomplished through the use of appliances similar to those used in humans. Such appliances include the inclined plane, the Herbst appliance and removable functional appliances of various types. The intraoral splints that have been designed and used by McNamara (1973,

1981) provide secure and controlled anterior displace- ment of the mandible in monkeys.

However, the anatomy and morphology of the rat's oral cavity presents peculiarities that make the use of such appliances quite problematical. A 10 mm edentulous space exists in both jaws between the incisors and the posterior molar teeth. As a result, interdigitating occlusal relationships leading to interlocking conditions do not exist in rats (Noble, 1980; Siegel and Mooney, 1990).

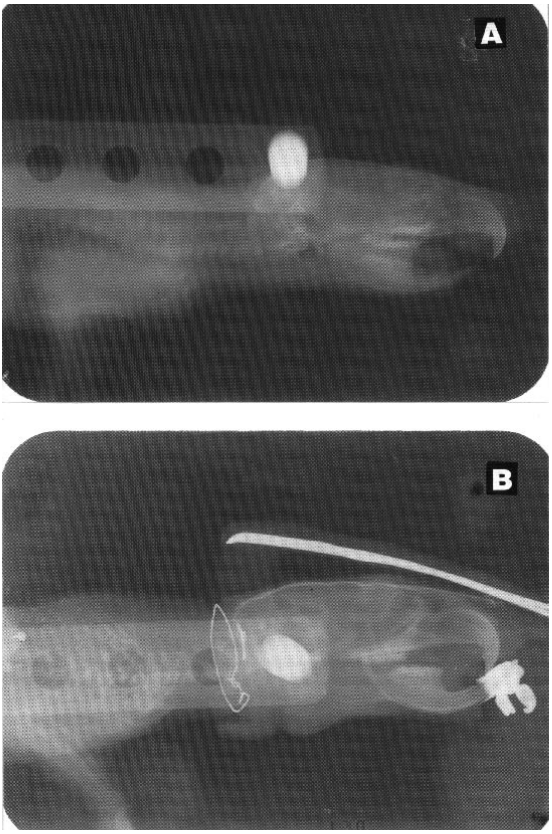


**Figure 4** (A) Lateral cephalometric radiograph of the rat without the appliance. (B) Lateral cephalometric radiograph of the rat wearing the appliance, demostrating hyper-propulsion of the mandible.

This morphology of the rat's dental arches in conjuction with the specific temporomandibular and symphyseal joints provide these animals with the ability to achieve free lateral and rotational movements of the lower jaw with more freedom of movement in lateral directions (Hiiemae and Ardran, 1968; Weijs and Dantuma, 1976). This ability makes control of the true hyper-propulsion of the lower jaw very difficult since any obstacle encountered during mandibular excursion can cause large lateral movements. Furthermore, it should be borne in mind that the rest position of the rat's mandible is 6 mm behind the attritional position and that the position of the molars coming into occlusion is even further back (Hiiemae and Ardran, 1968).

This is probably why an acrylic inclined plane described and applied by Petrovic *et al.* (1975) to fit on the anterior incisors of the lower jaw failed to produce a true and reproducible hyper-propulsion of the lower jaw. Specifically, this failure could be attributed to the rat's previously mentioned capacity to bring its mandible to the position of minimum discomfort and maximum rest. Due to the rat's extensive ability for large lateral excursions, the animals easily shifted the mandible to one side or the other, rather than keeping it in a straight, anteriorly protruded position.

Continuing the search for an effective hyperpropulsive appliance, the authors realized

**Table 1** Initial and final weight data (g).

| Group | Initial | | Final | | Difference ($t$ = 5.75, df= 22, $P < 10^{-4}$) | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| A | 42.92 | 0.90 | 117.83 | 1.75 | 74.92 | 1.51 |
| B | 43.75 | 1.91 | 123.58 | 3.18 | 79.83 | 2.55 |

Group A: rats wearing the hyperpropulsive appliance; group B: control rats.

that an inclined plane made of stainless steel orthodontic band material and cemented to the incisors of the upper jaw, similar to the one described by Ghafari and Degroote (1986), should at the same time have a substantial vertical dimension (height) in order to prohibit the animal from achieving a retrusion of the mandible backwards and downwards while attempting to avoid biting on the plane.

However, the width and height of the aforementioned inclined plane were so excessive that it was impossible for the animals to be fed properly with the appliance in place. This created serious problems regarding the animals' survival. Moreover, it was very difficult to remove and replace the appliance on a daily basis in order to facilitate feeding.

A gold cast inclined plane as described by Tonge *et al.* (1982) was also tested. When the vertical dimension was limited to 2 mm and the incisal edge was extended posteriorly by only 3.5 mm, as prescribed by these authors, it was almost impossible to eliminate the animal's effort to retrude the lower jaw in a backward position. These difficulties can be easily explained when it is considered that the position of the rat mandible while the molars are in occlusion is more than 6 mm behind that observed when the incisors are in occlusion. It must also be considered that the mouth can be opened at least 1 cm, as described by Hiiemae and Ardran (1968). Therefore, it is impossible to avoid a retrusive mandibular movement into a more posterior site of convenience by using castings extending posteriorly only 3.5 mm (Tonge *et al.*, 1982) or plane bite blocks of 5 × 5 × 3 mm (Tewson *et al.*, 1988).

Moreover, considering that scar tissue can develop on the nares by the hard stainless steel tubing used by Tewson *et al.* (1988), and could interfere with the nasomaxillary growth, it was thought preferable to avoid such a possibility. Taking into account the existence of an interaction in the growth process of the upper and lower dental arches, an interference in maxillary growth through any scar tissue may result in disturbed mandibular growth and development. Furthermore, possible underdevelopment of the premaxilla due to the above-mentioned trauma may lead to a false anterior crossbite in animal experiments using mandibular hyperpropulsion appliances.

Utilizing the previously mentioned appliances in pilot experiments, it was realized that severe problems resulted from the lack of reproducibility of the protruded mandibular position which these appliances induced. Hence, the reliability of the findings could be negatively influenced. After several trials, and in order to minimize errors in experiments involving mandibular hyperpropulsion, the appliance described in this paper was designed and subsequently used in a series of experimental projects (Spyropoulos *et al.*, 1997; Tsolakis *et al.*, 1997; Spyropoulos and Tsolakis, 1997).

## Conclusions

The appliance designed and described is composed of extra- and intra-oral portions that carry special auxiliaries for attachment of rubber bands aimed at forcing the rat's mandible into a protrusive position with measurable forces.

Its advantages in comparison with the appliances previously described in the literature are: (i) it provokes fully controlled, measurable, reproducible and secure anterior displacement of the mandible; (ii) it allows the animals to be fed sufficiently for a number of hours each day, as it is very easily removed and replaced; and (iii) it does not permit the animal to try and achieve any retrusive or lateral movements during the entire period of the experiment. This may be a very important variable which, if overlooked, could cause or lead to unexpected, confusing and unreproducible results.

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