# Effect of Age on the Adaptive Response of the Adult Temporomandibular Joint

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## A study of induced protrusion in *Macaca mulatta*

**Using occlusal and interproximal tooth wear as indicators of age, it is found that those animals with evident hypertrophy and hyperplasia of the condylar cartilage are among the youngest in the sample, supporting the view that adaptive potential of the temporomandibular joint may diminish with age.**

KEY WORDS: Mandibular growth, Functional therapy

While the responsiveness of the growing temporomandibular joint (TMJ) to changes in occlusion and functional jaw orthopedics has been well documented (Baume and Derichsweiler 1961, Stöckli and Willert 1971, Petrovic 1972, Petrovic et al. 1975, Adams et al. 1972, Cutler et al. 1972, Joho 1973, McNamara 1971, 1973, McNamara et al. 1975, McNamara and Carlson 1980, Hiniker and Ramfjord 1966), the adaptive potential of the adult or nearly adult TMJ remains uncertain. A number of studies have suggested that the capability for adaptive remodeling decreases or disappears with age (Adams et al. 1972, McNamara 1972, 1973, McNamara et al. 1975, Hiniker and Ramfjord 1966, Ramfjord and Enlow 1966, Ramfjord et al. 1971, Ramfjord and Blankenship 1981). In a recent attempt to clarify this issue (McNamara et al. 1982), we evaluated histologically the response of the TMJ in twelve young adult female rhesus monkeys *Macaca mulatta* fitted with fixed functional protrusive appliances for periods ranging from two to twenty-four weeks.

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Unlike the juvenile animals, considerable variability in TMJ response was noted. Half of the experimental subjects displayed tissue responses that were qualitatively (but not quantitatively) similar to those seen in juvenile animals. However, three animals developed crossbites in response to appliance placement and three animals who functioned anteriorly showed virtually no perceptible condylar response.

All animals were young, physiologically mature females with third molars in occlusion, but exact ages were not available. This made it impossible to investigate the direct relationship between chronological age and the variability in joint response.

This report describes —

1 The use of dental attrition data to establish relative ages of the experimental animals

2 The application of these relative ages to evaluate the extent to which chronological age can account for the variation in TMJ responsiveness to protrusive function.

Because of the almost universal presence of considerable attrition on the teeth of aboriginal human groups, the study of dental attrition has long been a tool of anthropologists seeking to reconstruct tooth usage and lifeway in peoples lacking or predating recorded history (MOLNAR 1972).

By making certain assumptions concerning eruption timing, stages of dental attrition have been used to assign chronological ages to individuals within a particular population (MILES 1962 AND 1963, SAGNE 1976, AND HELM AND PRYDSO 1979).

More recently, the degree of dental attrition has been shown to be highly correlated with known chronological age in living Eskimos (TOMENCHUK 1979) and Australian aborigines (RICHARDS AND BROWN 1981), and has proven an accurate method of establishing absolute and especially relative chronological ages in related test populations.

Assessment of attrition in the sample of monkeys analyzed here actually requires fewer assumptions than in human groups. All animals were housed in the same place and were fed an identical diet of monkey chow, thus minimizing the possible influence of different environmental or dietary conditions on rate of occlusal wear (SMITH 1972, WALKER 1978). Moreover, macaque molar teeth undergo attrition in a sequence which varies relatively little (GANTT 1979), and macaques show an extremely low incidence of tooth loss or malocclusion that might bias estimates of attrition.

## Materials and Methods

The experimental sample consisted of twelve adult female rhesus monkeys *(Macaca mulatta)*. From mandibular and maxillary alginate impressions taken on each animal, a mandibular appliance was constructed to induce a protrusive centric occlusal relationship (Fig. 1). The appliance caused a 2-3mm vertical (inferior) displacement of the lower jaw and a horizontal (anterior) displacement of 5mm. Animals fitted with the protrusive appliance were studied for periods of 2, 4, 6, 8, 12 and 24 weeks. A group of seven untreated animals served as controls. All animals were physiologically mature, with third molars in occlusion, making them at least 5.5 to 6 years of age (HURME AND VAN WAGENEN 1961).

Prior to sacrifice, each animal was heparinized and anesthetized with IM phencyclidine HCl and IV sodium pentobarbital. Following catheterization of the left ventricle or the carotid artery, the head was perfused with an AFA fixative (acetic acid, formalin, 95% ETOH) and placed into 10% neutral buffered formalin prior

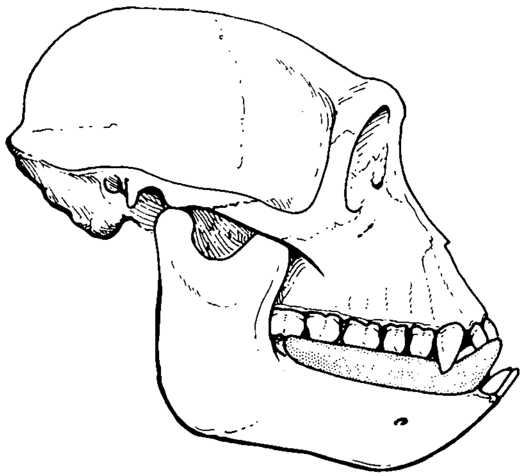


Fig. 1 Schematic representation of the protrusive appliance cemented on the mandibular arch. Note the forward and slightly downward positioning of the mandible.

to removal of the TMJ. Tissues were processed according to routine histological protocols, embedded in paraffin, sectioned at 18-22μm, and stained with either hematoxylin and eosin or Masson's trichrome stain.

The attrition analysis was based on casts of the maxillary dental arch of each experimental animal, made prior to appliance placement. Only the maxillary dental arch was used because it exhibited better preservation of occlusal morphology. The degree of occlusal attrition on the upper left maxillary first and second molars was scored on an ordinal scale with four levels of increasing cusp flattening and dentin exposure (Table 1). The scale is based on a similar rating scheme for humans (HINTON 1981), and is consistent both in sequence and form of wear to that established for a large series of macaques (GANTT 1979). In addition, the width of the interproximal wear facets between the second premolar and first maxillary molar and between the first and second maxillary molars was measured as described by HINTON (1982).

Table 1

Attrition levels in Assessment of occlusal wear on maxillary molars

| | |
|---|---|
| 1 | Minimal attrition, with no dentin exposure and only minor blunting of cusps |
| 2 | Considerable flattening of cusps and/or small dentin exposures |
| 3 | Moderate patches of dentin exposure, but still discrete |
| 4 | Coalescence of two or more areas of dentin exposure |

## Results

Levels of occlusal attrition on the maxillary first and second molars were summed to yield an estimate of overall tooth wear, thereby ranking individuals from a possible minimum summed score of 2 to a maximum of 8.

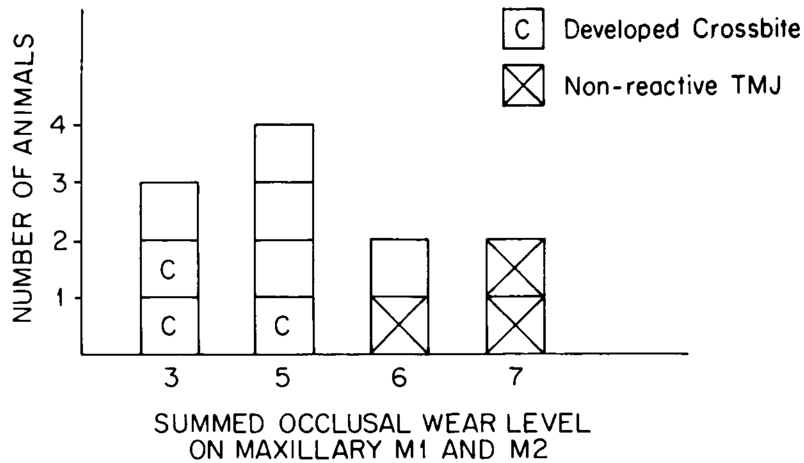



Fig. 2 Frequency distribution of experimental animals with respect to summed occlusal wear.

A frequency distribution for summed occlusal attrition in the experimental animals (Fig. 2) demonstrates relatively high levels of occlusal wear in all three animals that showed no TMJ response to the protrusive appliance. Two of these animals exhibit the greatest degree of occlusal attrition in the entire experimental sample, and the third animal is in the next highest wear category.

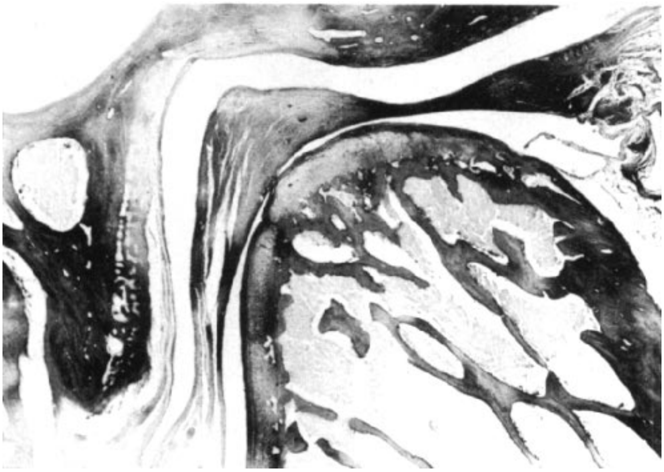
In contrast, those animals who displayed a definite histological response such as condylar hyperplasia, as well as those who developed a crossbite, are distributed primarily through the lower two wear categories. In general, the degree of histological response to protrusive function is inversely correlated with the amount of occlusal attrition (Figs. 3 and 4).

Variation in size of the interproximal wear facet, which has been shown to increase with independently-derived assessments of skeletal age (HINTON 1982), corroborates these findings. The width of the interproximal wear facet is from 33% to 40% larger in the two animals with the highest level of occlusal attrition than in the three animals with the lowest level (Fig. 5). Also, a frequency distribution for intervals of interproximal wear in the experimental animals shows the three non-reactive animals to have the largest amounts of interproximal wear in the entire sample (Fig. 6).

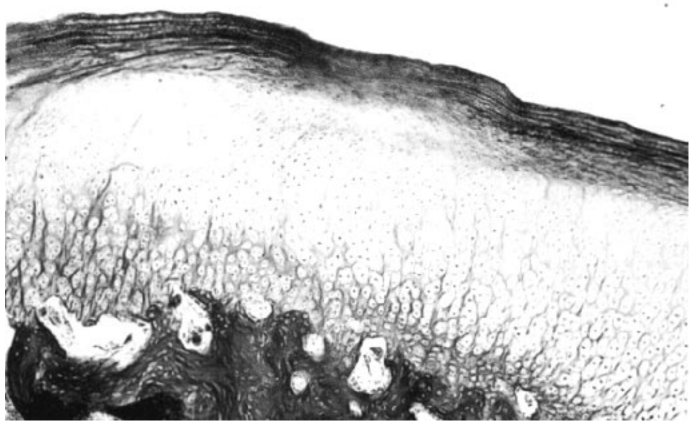
## Discussion

We believe that this data offers indirect evidence that the variability in temporomandibular joint response to protrusive function noted among these young adult monkeys may be due, in part, to differences in chronological age within the sample. This conclusion is based on the finding that the three animals who displayed no histological response at the TMJ were among the "oldest" in the sample, as assessed by occlusal and interproximal attrition, while the three "youngest" animals all exhibited distinct condylar responses.

Animals with intermediate levels of occlusal and interproximal attrition were



Temporomandibular joint region showing thickening of the condylar cartilage along the superior and posterior aspects of the condyle, and new bone along the anterior border of the postglenoid spine (8 weeks with splint; magnification ×9).



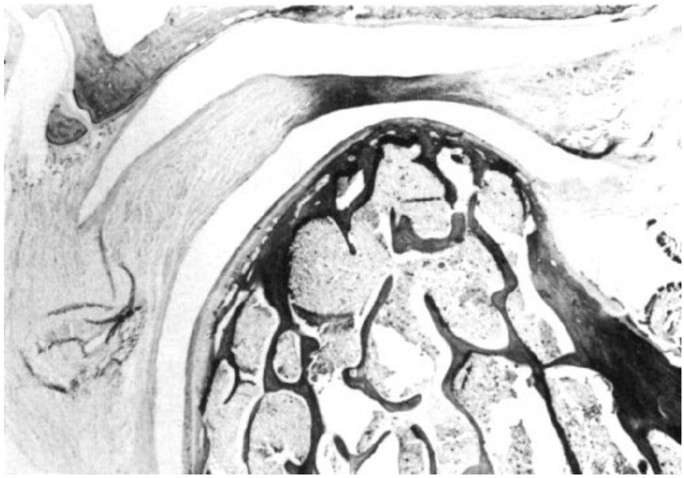
Condylar cartilage in the same animal along the superior surface of the condyle (magnification ×30). *Adapted from McNamara et al. 1982*

Fig. 3 Greatest histological response among the young adult monkeys in this study

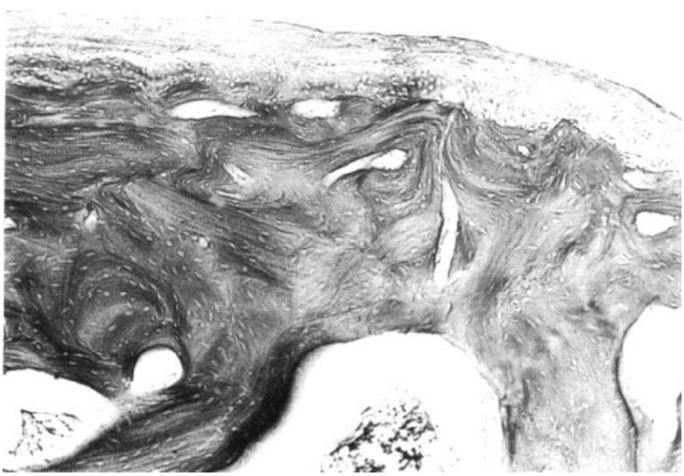
mixed in their histological response at the TMJ, perhaps due to idiosyncratic factors or to differences in chronological age too subtle to ascertain with the relatively crude measures employed here.

It is also of interest to note that development of a crossbite in response to appliance placement — a finding never encountered in juvenile animals — showed no apparent relationship to relative age as approximated here. However, for whatever reasons, two of the three adult animals who developed crossbites were among the youngest animals in the sample (Fig. 2); thus, it is perhaps not coincidental that they displayed distinct TMJ responses that are understandable in terms of the developed malocclusion (McNamara et al. 1982).

The finding that it was primarily the



Temporomandibular joint region showing virtually no response to the appliance (12 weeks; magnification ×9).



Condylar cartilage in the same animal. Note the thickness of the bony cap and the small number of cells (magnification ×30). *Adapted from* McN*amara et al.* 1982

**Fig. 4** Lowest level of histological response among the young adult monkeys in this study

older monkeys among this adult sample who failed to exhibit a histological joint response to the functional protrusive appliance supports the view that the temporomandibular joint loses the potential to adapt to occlusal changes as age increases. However, we cannot determine directly from these data *why* the older animals failed to exhibit a condylar response.

It might be supposed that the number and/or vitality of the prechondroblasts in the condylar cartilage declines with age, as has been demonstrated for the periosteum (Tonna and Cronkite 1962).

An alternative explanation might be that the older animals were unable, due to some deficit in neuromuscular function, to posture the lower jaw forward to the extent required by the appliance, thus

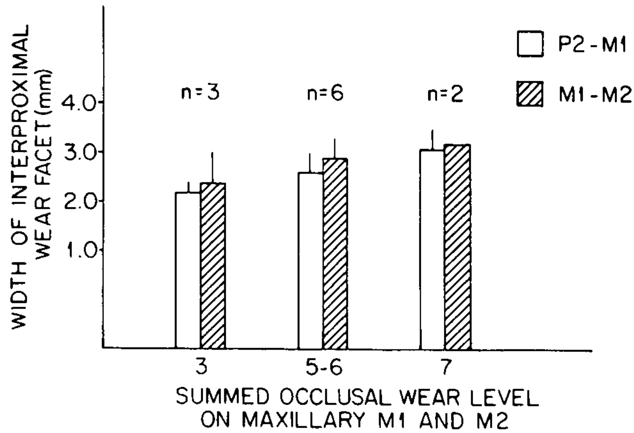



Fig. 5
Mean interproximal wear facet width in samples stratified by summed occlusal wear on the first and second maxillary molars.

providing insufficient stimulus for condylar growth. The appliance is designed to require protrusion for closure; protrusion can be avoided only by maintaining the jaw in an open or laterally displaced posture. These postures were indeed observed in animals who developed crossbites, two of which were among the youngest animals as determined from attrition, and were accompanied by characteristic histological changes in the postglenoid spine (McNamara et al. 1982).

If the lack of response in the three oldest animals were due to a lack of protrusion, then we would expect evidence of occlusal aberrations such as crossbite, or perhaps histological changes in the postglenoid spine. As neither of these effects was noted in any of the nonresponding animals, we feel that a lower adaptability of the joint tissues is the more likely explanation.

These findings are also intriguing because the entire sample was probably

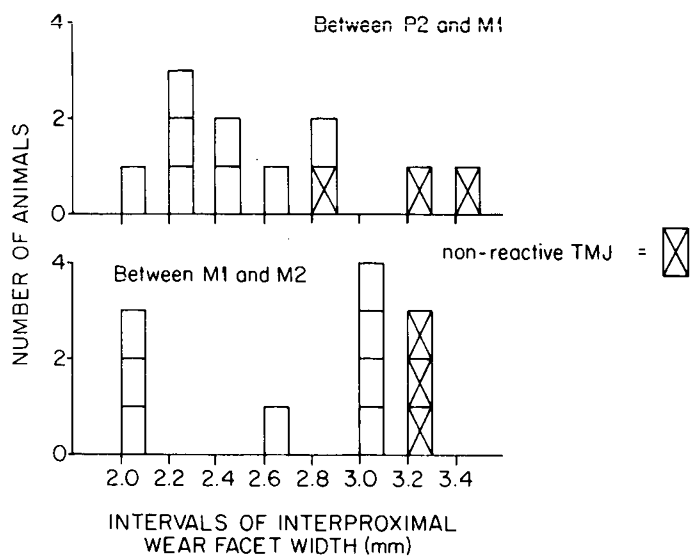



Fig. 6
Frequency distribution of experimental animals with respect to width of interproximal wear facet.

composed of relatively young adults, based on descriptions of tooth wear in older monkeys (BUTLER AND BERNSTEIN 1974) and on attrition levels found in two animals of known chronological ages.

In the only two adult animals for which birthdates were known, occlusal wear had reached stage 2 on the upper first molar, and was between stages 1 and 2 on the upper second molar. Widths of the interproximal wear facets in these two animals were 2.1 and 2.2mm between the second maxillary premolar and first molar, and 2.3 and 2.1mm between the first and second maxillary molars. Both animals were between 7 and 7.5 years of age at the time the dental impressions were taken. Thus it is likely that the youngest of the animals in our sample were around this age, just entering young adulthood.

On this basis, our data suggests that the adaptive potential of the TMJ, at least in monkeys, may undergo a reduction relatively early in adult life. However, this inference must be tempered by the realization that other factors, such as the nature of the appliance and perhaps the duration of treatment, may also affect the response. For example, a recent cephalometric study by two colleagues (SCHEIDERMAN AND CARLSON 1981) found significantly greater condylar growth in young adult animals fitted with a bite-opening appliance that produced a 15mm open bite at the incisors than in control animals. Condylar growth increments larger than those in the controls were noted even in animals with tooth wear in excess of that found in the oldest animals in the present study.

## Conclusions

In young adult female monkeys fitted with a protrusive appliance, ranking of experimental subjects by "ages" derived from occlusal and interproximal attrition suggests that part of the observed variability in histological TMJ response may be related to differences in age within the sample. This finding supports the view that responsiveness of the TMJ to altered functional demands may diminish with age.

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