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Histological aspect of the effects of soft food on major salivary glands

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ABSTRACT : The modern Japanese population favors soft foods, which do not demand extensive mastication. However, daily intake of soft foods is considered to have unfavorable influences on the mind and body. This is especially within the oral maxillofacial region. Consequently, many studies using experimental animals, feed a liquid or powdered diet and indicate that soft foods negatively affect the jaw bones, masseter muscle, and temporomandibular joint. Furthermore, since a report by Hall and Schneyer in 1964, the effects of soft foods on salivary glands have been under investigation. Soft food intake induces atrophic alteration to the parotid glands in adult animals. In these glands, shrinkage, suppression of proliferation, and apoptotic deletion of acinar cells were observed. In growing animals fed soft foods, parotid gland growth is inhibited through the suppression of an increase of acinar cell size and of acinar cell proliferation, but not through apoptosis. These findings support that unfavorable effects on parotid glands are induced by the intake of soft food regardless of growing or mature phases. However, different observations exist between these two phases. Despite accumulated knowledge on parotid glands, the debate whether soft food affects submandibular and sublingual glands remains controversial. It is the case that many studies agree soft food unfavorably affects parotid glands to a greater extent than submandibular and sublingual glands. This article reviews the histological effects of soft food on major salivary glands and introduces recent data from our research group.

Key Words : soft food, major salivary glands, atrophy, cell proliferation, apoptosis

Introduction

Over several decades, a majority of the Japanese population has frequently relied on ready-to-eat meals, many of which are processed and frozen. This trend has therefore increased the consumption of soft foods that do not require extensive mastication[1-3)]. According to Yanagisawa *et al.*[4)], about 60 percent of the foods eaten daily in Japan are soft. There are now concerns that such a dietary habit might negatively influence health of the mind and body, especially within the oral maxillofacial regions. To investigate this problem, an experimental model of feeding soft foods to animals is widely used. Based on findings from these studies, a smaller maxilla and mandible[5-7)], low mineral apposition in the jaw bones[8)], reduction of remodeling of jaw bones[9)], atrophy of the masseter muscle, alterations in the composition of the muscle fiber types[10-13)], low growth of the temporomandibular joint[14, 15)], and alterations in collagens and chondrocytes in the temporomandibular joint cartilage[16)] are reported.

Salivary glands are important exocrine glands to maintain health of the oral cavity. Therefore previous investigators have reported on cell morphology and function of the salivary glands. In 1964, Hall and Schneyer[17)] first reported the effects of soft food on

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salivary glands. In their investigation, three to five-month-old rats were given a liquid diet for 14 days, and three major salivary glands were examined. Weight of the parotid glands was remarkably reduced (39-52%), and those of the submandibular and sublingual glands were lightly decreased (14-32%). Although the duct cells were histologically unchanged, shrinkage of the acinar cells was observed in all three major salivary glands[17]. This report has attracted a lot of interest in salivary gland research, and ensured that the effects of soft food on salivary glands are studied further.

This review describes the histological findings on major salivary glands accumulated by previous investigators in addition to describing our own current research with discussion on the effects of soft food on major salivary glands.

1. Effects of soft food on parotid glands

According to previous reports, parotid gland weight is decreased in animals fed a soft diet. In these atrophic parotid glands, decreases in the diameter and individual area of the acinar cells were demonstrated by histomorphometric analysis[18, 19], suggesting that predominantly shrinkage of acinar cells causes parotid gland atrophy. Using electron microscopy, it has also been reported that degenerate[20] and necrotic[21] acinar cells are observed in the atrophic parotid glands, and that the gland DNA content is reduced[22]. Taking these data into consideration, atrophy of parotid glands in experimental animals fed soft diets might be induced not only by shrinkage of acinar cells but also by decreased acinar cell number.

It is difficult to directly count the total number of acinar cells in the parotid glands. We therefore investigated acinar cell proliferation and apoptosis during atrophy of parotid glands in rats fed a liquid diet to determine changes in acinar cell number. Reportedly, apoptosis often plays an important role in removal of acinar cells during atrophy of salivary glands induced by several pathological conditions[23-28]. In our investigation[29], rats in the experimental group were fed a liquid diet and compared to pellet-fed control rats. The parotid glands were examined using histological analysis, immunohistochemistry for 5-bromo-2'-deoxyuridine (BrdU) and cleaved-caspase-3 (Casp-3) as makers of cell proliferation and apoptosis, respectively, and transmission electron microscopy (TEM). In the experimental parotid

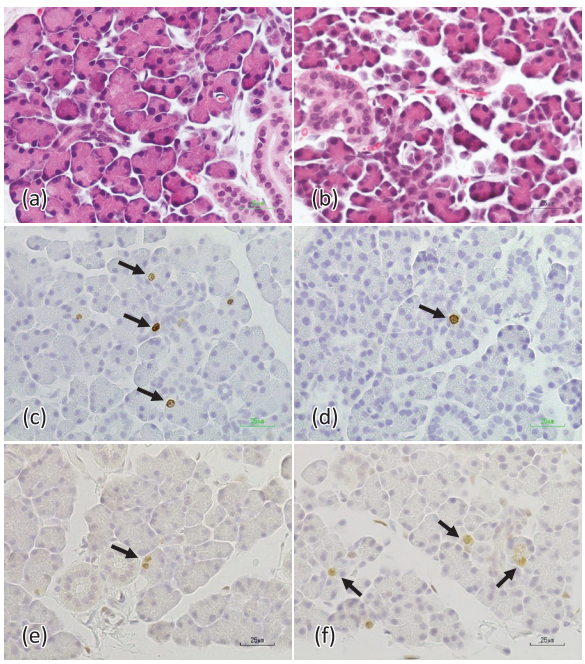

Fig. 1 Mature parotid glands of rats fed a pellet diet (control) (a, c, e) and a liquid diet (experimental) (b, d, f) ; HE on day 21 (a, b), BrdU on day 14 (c, d), Casp-3 on day 7 (e, f), Scale bars=25μm.
Acinar cells in experimental parotid glands (b) are smaller than in control glands (a). There are more BrdU-positive acinar cells (arrows) in control glands (c) than in experimental glands (d). More Casp-3-positive acinar cells (arrows) are identified in experimental glands (f) than in control glands (e).

glands, acinar cells were reduced in size (Fig. 1a, b) and numbers of BrdU-positive acinar cells were decreased (Fig. 1c, d) as the parotid gland weight was reduced. Furthermore, there were more Casp-3-positive acinar cells in the experimental parotid glands than in the control glands (Fig. 1e, f), and acinar cells with a typical appearance of apoptosis were often identified by TEM. Our findings showed that acinar cell number decreased with lower proliferative activity and increased apoptosis in the parotid glands of rats fed a liquid diet. Therefore, it could be considered that decreased acinar cell number, as well as decreased acinar cell size, participate in atrophy of parotid glands of liquid-fed rats[29].

It is well known that children particularly tend to prefer soft foods to hard foods[30, 31], and the influence of this dietary habit on growth of the oral maxillofacial regions is a clinical concern[32, 33]. We therefore used infant rats that immediately after weaning were fed a liquid diet for 8 weeks to clarify the effects of this on parotid gland growth[34]. Parotid gland weight of the pellet-fed rats increased considerably, while that of the liquid-fed rats increased only marginally. In the pellet-fed rats,

acinar cells were initially small (Fig. 2a), but grew larger over time (Fig. 2b). However, acinar cell size remained almost unchanged in the liquid-fed rats over time (Fig. 2c). In both groups, BrdU-positive acinar cell numbers were high at the beginning of the experiment (Fig. 2d), but decreased over time. However, numbers in the liquid-fed rats were decreased to a greater extent than in the pellet-fed rats (Fig. 2e, f). Casp-3-positive acinar cells were rarely identified in both groups. These observations in our study demonstrate that liquid diet feeding inhibits growth of parotid glands in growing rats through suppression of growth in size and proliferation of acinar cells, but not through apoptosis[34].

It can be concluded from this section that unfavorable effects on parotid glands are induced by intake of soft food regardless of growing or mature phases. In the next section, we describe the effects of soft food on two other major salivary glands.

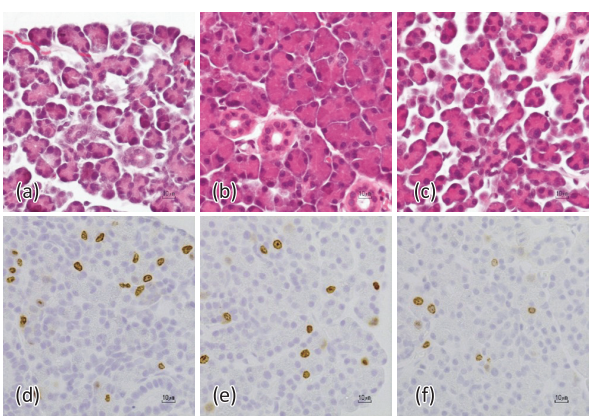

Fig. 2 Growing parotid glands of rats fed a pellet diet (control) (a, b, d, e) and a liquid diet (experimental) (c, f) ; HE at week 0 (a) and week 4 (b, c), BrdU at week 0 (d) and week 1 (e, f), Scale bars=10μm.
Acinar cells are small at the start of experimentation (a), but become larger in the control gland over time (b). Acinar cells are unchanged in the experimental glands over time (c). BrdU-positive acinar cells are common in control glands (d, e), but are fewer in experimental glands (f).

2. Effects of soft food on submandibular and sublingual glands

Despite accumulated knowledge concerning the effects of soft diet on parotid glands, fewer reports have investigated these effects on submandibular and sublingual glands[35-40]. Although many studies report that soft food does not induce atrophy in the submandibular glands[35-38], but other studies contradict this[39, 40]. Similarly, Mansson et al.[36] and Kurahashi and Inomata[38] report that sublingual glands become atrophied by soft food feeding, however this effect was not observed in other studies[19, 35, 37]. Consequently, whether soft food affects submandibular and sublingual glands remains highly controversial.

We therefore examined these glands using the same experimental model[41]. In the mature submandibular and sublingual glands, there was no difference in gland weight, acinar cell size (Fig. 3), proliferative activity of the acinar cells, occurrence of acinar cell apoptosis, and ultrastructure between the pellet-fed and liquid-fed rats, indicating that the liquid diet does not affect these two mature glands[41]. The salivary glands in growing rats fed a liquid diet were also examined[42]. Although the liquid diet had no effect on the growing submandibular glands (Fig. 4a-c), acinar cells smaller in size and with lower proliferative activity were observed in the growing sublingual glands from the liquid-fed rats compared with the pellet-fed rats at 8 weeks (Fig. 4d-f). Despite these changes in the sublingual glands, sublingual gland weight was comparable between liquid-fed and pellet-fed rats throughout the growth period. It is possible that these effects might be too weak to affect sublingual gland weight enough to be detected numerically. Regardless of this, our results showed that growing sublingual glands were influenced very slightly by the liquid diet[42].

As described above, differences in results exist between studies, including our own. This may be due to the subtle differences in experimental conditions employed in each study, such as the nature of the

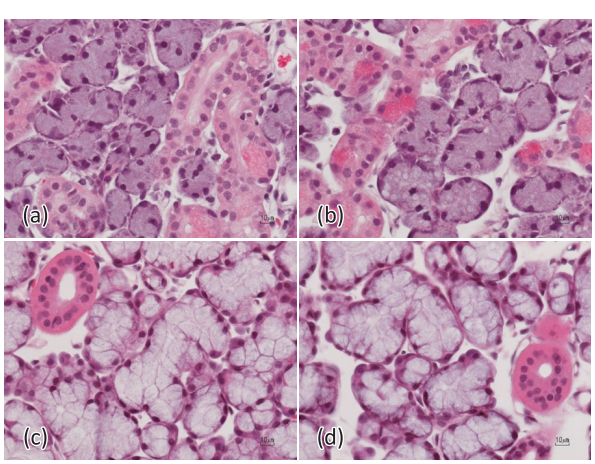

Fig. 3 Histology (HE) of mature submandibular (a, b) and sublingual glands (c, d) of rats fed a pellet diet (control) (a, c) and a liquid diet (experimental) (b, d) on day 7 ; Scale bars=10μm.
The morphology of acinar cells in control glands (a, c) is similar to that in experimental glands (b, d).

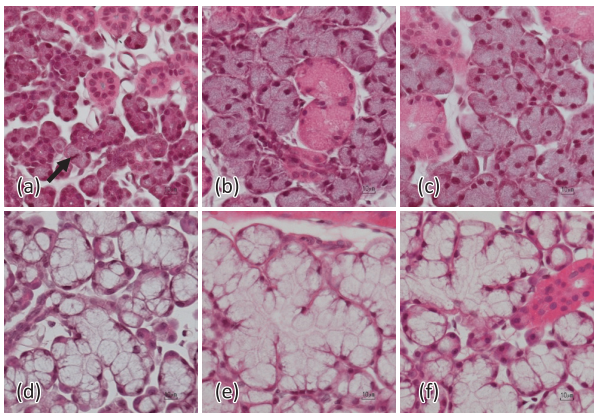

Fig. 4 Growing submandibular (a, b, c) and sublingual glands (d, e, f) of rats fed a pellet diet (control) (a, b, d, e) and a liquid diet (experimental) (c, f) ; HE at week 0 (a, d) and week 8 (b, c, e, f), Scale bars=10μm.
Small acinar cells are observed in submandibular (a) and sublingual glands (d) at the start of experimentation. Mitotic figure of an acinar cell (arrow) is shown. Acinar cell morphology in control submandibular glands (b) is similar to that in experimental glands (c) throughout the feeding period. Acinar cells in experimental sublingual glands (f) are a little smaller than in control glands (e) at week 8.

soft food (liquid or powdered diet, ratio of mixture of powdered diet and water) and length of the experimental period. Therefore, further studies are necessary to clarify these exact reasons.

Concluding remarks

Although controversy exists on the effects of soft diet on major salivary glands, we can conclude that soft food unfavorably affects parotid glands to a greater extent than submandibular and sublingual glands. Based on the major highlights of this review, it is clear that diet and mastication are necessary to maintain healthy salivary glands and promote salivary gland growth. We would therefore emphasize that dental scientists and clinical dentists should appeal to the general public on the importance of dietary habit and mastication.

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