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Relationship between accessory foramina and tumour spread in the lateral mandibular surface

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ABSTRACT

The spread of tumour cells to the mandible has been well recognised and invasion of the edentulous alveolar ridge by tumour through accessory foramina has been documented. Tumour infiltration can also occur through the lateral cortical plate, but the number and distribution of accessory foramina on this surface has not been reported. Lateral surfaces of 89 mandibles were examined and accessory foramina which showed a direct communication with the underlying cancellous bone were charted. It was found that the number of accessory foramina varied greatly from specimen to specimen. Only 70.8% of mandibles showed foramina in the coronoid, sigmoid and condylar sections; of these 93.7% exhibited foramina in the condylar section, 23.8% in the coronoid and only 19% in the sigmoid section. This finding confirms that the current practice of conserving part of the ascending ramus posterior to the coronoid process following surgery is sound. Similarly in the rest of the lateral surface, foramina were present in the upper third section in 97.8% of mandibles, 61.8% in the lower third and 58.4% in the middle third sections. This result justifies the principle of rim resection in appropriate cases and the recognition that the alveolar section is commonly invaded before the rest of the body. The number and distribution of foramina may be of greater significance following radiotherapy when the foramina could provide multiple direct channels for invasion of tumour cells from the lateral surface to the medulla.

Key words: Mandible; carcinoma; malignant invasion.

INTRODUCTION

Accessory foramina on the edentulous ridge of mandibles have been found to play a substantial role in the invasion and spread of cancer cells (Barttlebort et al. 1987; McGregor & MacDonald, 1988). Although tumour cells were found to invade non-irradiated mandibular bone mainly via the alveolar crest, studies showed that infiltration was also frequently associated with the lateral cortical plate (McGregor & MacDonald, 1988) in a substantial number of cases (Hoppe & Donath, 1987) and the site of entry was noted to be dependent on the location of the tumour in relation to the jaw (Slootweg & Muller, 1989). Following radiotherapy, tumour invasion was found to be more widespread and aggressive, and entry was commonly gained through the cortical plate via the periosteal surface to proliferate towards the medulla (Carter et al. 1980; O'Brien et al. 1986; McGregor & MacDonald, 1988); in addition, there was a loss of predictability in the pattern of spread generally and foci of invasion through sites other than the occlusal surface were seen more frequently (McGregor, 1993). It therefore appears that tumour cells may gain entry into the mandible not only via the foramina on the occlusal ridge, but also via foramina in other parts of the mandible especially following radiotherapy. Once the medulla is reached, then the inferior dental canal is accessed with the potential for perineural spread (Byars, 1952).

The presence of multiple foramina on the alveolar ridge following extraction of teeth has previously been described (Neufeld, 1958; Atwood, 1963; Lammie, 1966). Foramina on the mandibular surface have also been counted previously (Sutton, 1974; Haveman & Tebo, 1976) in order to find a reason for failure of anaesthesia following inferior alveolar blocks. However, in order to understand the mode of tumour spread, the number and distribution of foramina actually communicating with the cancellous bone is required because this direct pathway provides the most efficient route from the periosteum to the medulla. This information has not been reported previously. A study was therefore undertaken to establish the distribution pattern of those accessory foramina on the lateral mandibular surface which were observed to communicate directly with the underlying cancellous bone. Dentate and partially dentate mandibles were selected for this study as there is already a substantial number of reports on of the edentulous alveolar crest (Barttlebort et al. 1987; McGregor & MacDonald, 1988; Slootweg & Muller, 1989).

MATERIALS AND METHODS

A total of 89 soft tissue denuded adult human mandibles of unknown origin were examined. 54 mandibles were dentate on both sides, 18 were partially dentate on one side and 17 were partially dentate on both sides. The surface of all mandibles examined was intact with no evidence of bone pathology, and no known history of radiation therapy. For convenience of measurement a horizontal line was drawn midway between the deepest curvature of the sigmoid notch and a point on the lateral mandibular surface corresponding to the inferior dental foramen. Part of the lateral surface above this line was identified as the superior region and the part below it as the inferior region (Fig. 1). The left and right superior regions were each further subdivided into condylar, sigmoid and coronoid sections and the inferior region into upper, middle and lower third sections. The inferior dental and mental foramina and the edentulous occlusal aspect of the partially dentate areas were excluded from measurement. In partially dentate specimens the foramina on the alveolar ridge were differentiated from those on

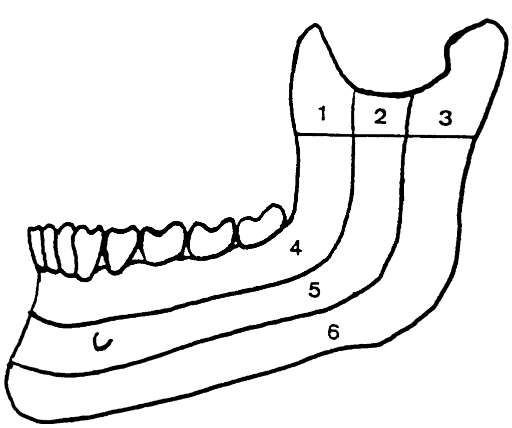

Fig. 1. Lateral mandibular surface showing the 6 sections: 1 = coronoid, 2 = sigmoid, 3 = condylar, 4 = superior third, 5 = middle third and 6 = lower third.

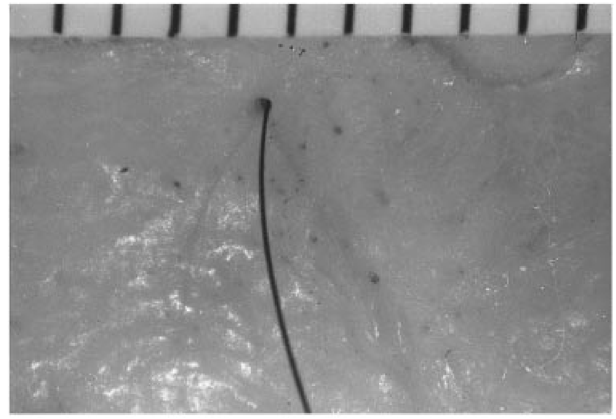

Fig. 2. Photograph of a foramen situated below crown of first premolar. The bristle passes through the foramen into the cancellous space. The marking is in millimetres.

the lateral surface by positioning the mandible such that only the foramina on the lateral surface were visible during the counting procedure.

In order to identify the foramina clearly, a dissection microscope using a magnification of $\times 9$ to $\times 20$ and fitted with a dual fibrelight system was used. Numerous foramina were observed on the cortical surface, but only those which showed a definite communication with the underlying cancellous bone were included in the study (Fig. 2). This was facilitated by shining a fibrelight beam through the foramen or by passing a fine bristle through it.

The number of accessory foramina in corresponding sections of the left and right superior and inferior regions were added together. There were therefore, 6 counts available from each mandible and the analysis aims to describe these in the following way. First, the total number of foramina on each mandible was obtained. Secondly, the relative distribution of the foramina between the superior and inferior regions was described by calculating the proportion of foramina that were found in each of these 2 regions. The final stage of the analysis considers the relative distribution of foramina between the sections within each of the superior and inferior regions. This was done by expressing the number of foramina within each section of the inferior region as a proportion of the total number in that region and similarly for the superior region. The data are highly variable and are described using median and centiles and appropriate graphs.

RESULTS

Total number of foramina

The total numbers of accessory foramina counted on the lateral surface of the mandible are shown in

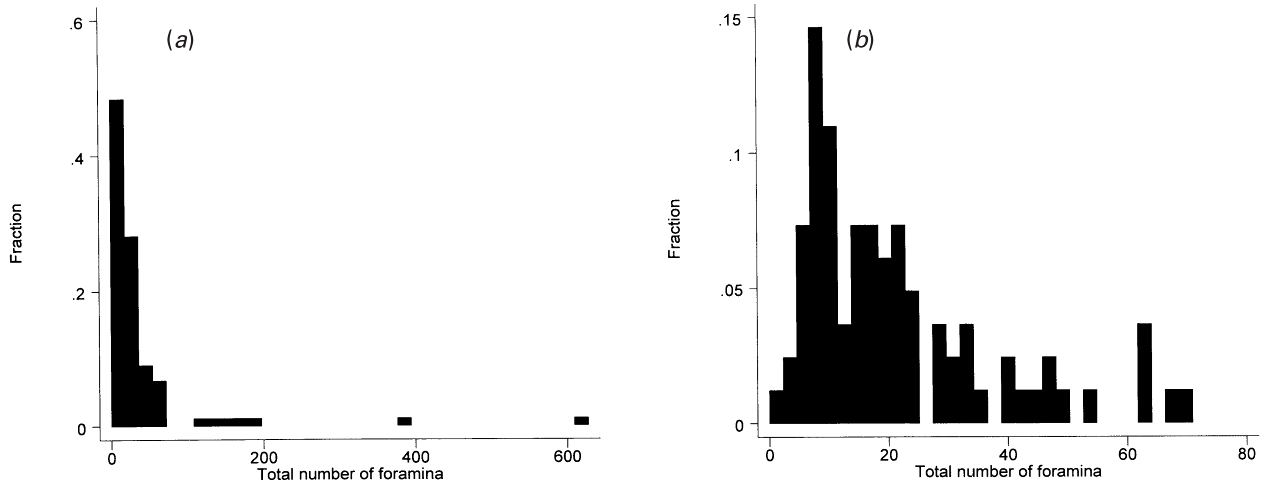

Fig. 3. Histograms of the total number of foramina on each mandible: (*a*) all mandibles; (*b*) the 82 mandibles with less than 100 foramina. Vertical axis plots fraction of total sample.

Table 1. *Summary statistics for the total number of foramina in each section of the lateral mandible*

	Minimum	10th centile	Lower quartile	Median	Upper quartile	90th centile	Maximum	Number (%) of zeroes
Total	2	6	10	18	34	68	627	0 (0)
Upper	0	3	6	13	27	53	263	2 (2.2)
Middle	0	0	0	1	2	10	204	37 (41.6)
Lower	0	0	0	1	4	10	58	34 (38.2)
Coronoid	0	0	0	0	0	2	30	74 (83.1)
Condyle	0	0	0	1	4	5	58	30 (33.7)
Sigmoid	0	0	0	0	0	1	17	77 (86.5)

Table 2. *Summary statistics for the proportions of foramina in the inferior and superior regions of the mandible*

	Minimum	10th centile	Lower quartile	Median	Upper quartile	90th centile	Maximum	Number (%) of zeroes
Inferior	0.41	0.6	0.79	0.89	1.0	1.0	1.0	0 (0.0)
Superior	0	0	0	0.11	0.21	0.4	0.59	26 (29.2)

Figure 3. Panel *a* is a histogram of the whole sample and shows that the number of foramina varies greatly between specimens. As the scale is so dominated by the few mandibles with large numbers of foramina it is useful to consider panel *b*, which is a histogram for the 82 mandibles with under 100 foramina, excluding 7 mandibles with, respectively, 114, 140, 150, 173, 196, 386 and 627 foramina.

Numerical summaries of the number of foramina are given in Table 1, where the usual 5-figure summary of minimum, maximum, median and quartiles is supplemented by the 10th and 90th centiles and the numbers within each region are also summarised. The large number of mandibles with no foramina in some regions means that it is also useful to present the proportion of mandibles with no foramina, either in total or within a region; this statistic is also given in Table 1. The percentage of mandibles with no foramina in a given section of the lateral surface varied from 2.2% in the upper third section to 86.5% in the sigmoid section.

Variations between superior and inferior sections

Table 2 shows a numerical summary of the proportions of foramina in the coronoid, condylar and sigmoid sections (superior region) and in the upper, middle and lower third sections (inferior region). It

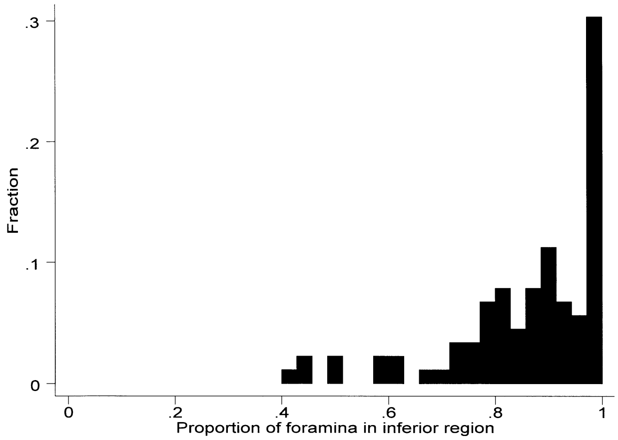

Fig. 4. Histogram of the proportion of foramina in the inferior region. Vertical axis plots fraction of total sample.

was found that the superior region had proportionately fewer foramina than the inferior region and in 29.2% of mandibles the superior region exhibited no foramina at all. The proportion of the foramina in the inferior region is described by the histogram in Figure 4. The large peak at 1 corresponds to the 70.8% of mandibles in which all foramina appeared in the inferior region; in this sample the inferior region never contained fewer than 40% of the foramina and for most mandibles the proportion of foramina in the inferior region was between 0.8 and 1.0.

Disposition of foramina within the superior and inferior regions

Table 3 and Figure 5 summarise the number of foramina in the coronoid, condylar and sigmoid sections and upper, middle and lower third sections as a proportion of the numbers in the superior and inferior regions respectively. The proportions in the superior region could not be calculated for 26 mandibles which did not show any foramina in this region, so the summaries for this region are restricted to the remaining 63 mandibles.

In the superior region the condylar section showed the greatest proportion and in the inferior region the upper third section showed the greatest proportion of foramina. Graphical display of triplets of proportions such as those analysed here is complicated by the constraint that the proportions necessarily sum to one. Pairs of proportions could be displayed but this is unsatisfactory because it requires an arbitrary choice of 2 from 3 variables. The plots in Figure 5 overcome this by using the following result: for any point P in the interior of an equilateral triangle of unit altitude the perpendicular distances from each side to P sum to one. Thus we can establish a coordinate system in which each vertex represents one variable having proportion one and the other 2 being zero. Thus in Figure 5*a*, mandibles in which all foramina were in the middle region would be plotted at the top vertex. A mandible with 50% of its foramina in the lower third and 50% in the upper third would be plotted at the midpoint of the base. A point with proportions (upper, middle, lower) = (a,b,c) would be plotted at a point a units perpendicularly from the SW–NE side, b units perpendicularly from the base and c units perpendicularly from the NW–SE side.

The proportions in the 3 sections of the inferior region are shown in Figure 5*a*, with those in the superior region shown in Figure 5*b*. To avoid coincident points obscuring one another the points have been slightly 'jittered' by the addition of a small random disturbance. The 26 mandibles with no foramina in the superior region are represented in Figure 5*b* by a point at the centroid. Further information is contained in Figure 5 as points representing mandibles with more or fewer than the median number of foramina (in total, so median is 18) are plotted with different symbols.

Table 3. *Summary statistics for the proportions of foramina within sections of the inferior and superior regions; summaries in the superior region apply to the 63 mandibles with at least one foramen in that region*

	Minimum	10th centile	Lower quartile	Median	Upper quartile	90th centile	Maximum	Number (%) of zeroes
Inferior								
Upper	0	0.43	0.67	0.84	0.98	1.0	1.0	2 (2.2)
Middle	0	0	0	0.05	0.13	0.25	0.67	37 (41.6)
Lower	0	0	0	0.08	0.2	0.33	1.0	34 (38.2)
Superior								
Coronoid	0	0	0	0	0	0.4	1	48 (76.2)
Condyle	0	0.33	0.8	1.0	1.0	1.0	1.0	4 (6.3)
Sigmoid	0	0	0	0	0	0.25	1.0	51 (81.0)

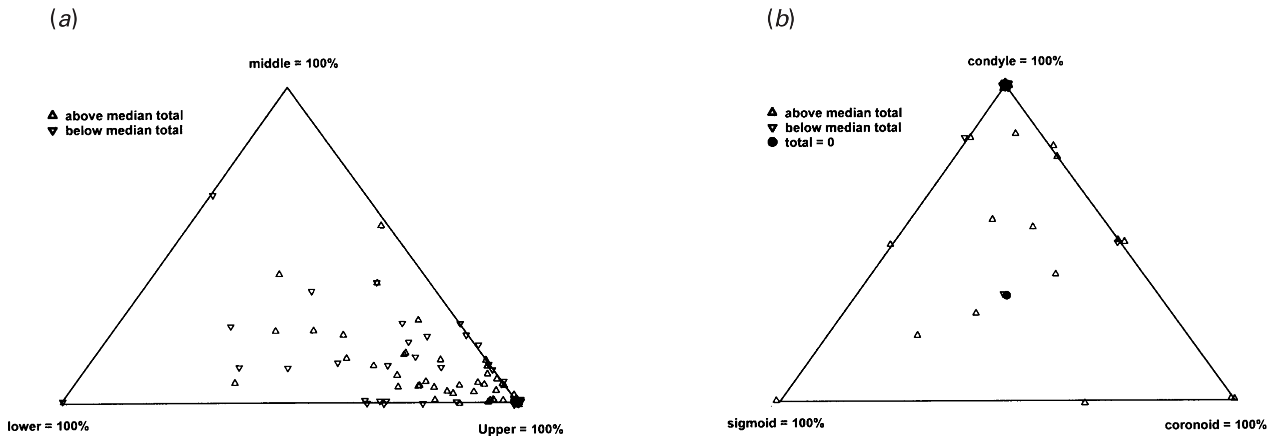

Fig. 5. Equilateral triangle plots (see text for details) of proportions in the inferior (*a*) and superior (*b*) regions. Points representing mandibles with more or fewer than the median number of foramina (18) are plotted using different symbols.

It can be seen that in the inferior region most points are clustered near the SE corner of the plot, showing that in the inferior region most foramina are in the upper third section, whereas in the superior region most are in the condylar section.

DISCUSSION

The lack of predictability of tumour spread has been well documented and this has been confirmed by the finding that the number of foramina varies enormously from mandible to mandible. The number of mandibles with no foramina in a given section is substantial for all sections other than the upper third where 97.8% of all mandibles have some foramina. The upper third section which includes the alveolar buccal plate also showed the greatest concentration of foramina compared with all other sections. If it is recognised that foramina which communicate directly with cancellous spaces provide the most efficient route for tumour spread, then the present findings confirm the current surgical policy of rim resection of the mandible in appropriate cases. In 41.6% of specimens the middle third section and in 38.2% of specimens the lower third section of the inferior region did not exhibit any foramina. This finding is of equal importance because it supports the observations that the upper third of the body is most vulnerable (McGregor, 1993).

In 86.5% of specimens the sigmoid section and in 83.1% of specimens the coronoid section did not show any foramina. For cases where the retromolar area and coronoid process are removed as part of a surgical resection procedure leaving the rest of the ascending ramus intact, this study confirms the comforting observation that the sigmoid region has the least number of foramina compared with all other sections in all the mandibles examined. Two patterns of invasion of squamous cell carcinoma in the mandible are recognised. The erosive pattern which advances on a broad front where a conservative surgical approach may be possible and the invasive pattern where there is diffuse growth in the cancellous bone canal and removal of the entire thickness of the mandible becomes necessary (Slootweg & Muller, 1989; Brown & Browne, 1995).

In nonirradiated edentulous mandibles, invasion by cancer cells was found to occur mainly via the edentulous alveolar crest but also frequently through other parts of the mandible (Hoppe & Donath, 1987; McGregor & MacDonald 1988; Slootweg & Muller, 1989). Brown & Browne (1995) found that the alveolar crest was the preferred site of entry in only 5 of their 33 reported cases. Invasion in parts of the mandible other than the alveolar crest was however, more commonly observed in irradiated mandibles when multiple foci of spread were in evidence and the tumour eventually reached the medulla (Carter et al. 1980; O'Brien et al. 1986). In a study of 16 irradiated mandibles McGregor & MacDonald (1988) found that in 6 cases the buccal plate and in 4 cases the more resistant lower border was invaded by squamous cell carcinoma. They came to the conclusion that radiotherapy was thought in some way to diminish the ability of the periosteum to function as a barrier to tumour spread. It appears that accessory foramina communicating directly from the surface into the medulla, in the presence of radiation induced endarteritis coupled with a total lack of host reaction (McGregor & McGregor, 1986) will account for the way in which multiple foci of tumour invasion occur via the lateral surface of the mandible.

In conclusion, a knowledge of the distribution of foramina helps to explain the mode of tumour spread on the lateral mandibular surface and confirms the current policy of adopting conservative surgical methods in suitable cases. A further study is in progress to determine the distribution of foramina on the medial surface of the mandible.

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