Morphologic Characteristics of Bony Edentulous Jaws

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Purpose: The objective of this study was to examine bone tissue characteristics of edentulous arches and residual ridges in different regions of the human jaws.

<u>Materials and Methods</u>: For the study, 24 maxillary and 99 mandibular completely edentulous dry specimens were examined macroscopically and by linear and caliper measurements. Width and length of the edentulous arches were registered from the molar regions to the crest of the incisor zone. Residual ridges were quantified at the incisor, premolar, and molar regions.

<u>Results</u>: Arches and ridges varied in size and shape. A trabecular bone track was present at the edentulous surface. In the maxillary arch, trabecular tissue was external to the cortical palatal vault, and in the mandible, the trabecular bony stretch was inside the cortical plates along the entire edentulous surface of the jaw. Of the ridges, 38% were thin knife-edged. In the maxilla, bone resorption was centripetal, and the crest of the edentulous arch was external to the osseous base of the cranium. In the mandible, resorption was centrifugal, forming an edentulous crest lingual to the mental protuberance anteriorly and to the mandibular base posteriorly. This discrepancy produced a reverse horizontal overlap of the residual crests, where the edentulous maxilla was at the same level or internal to the facing edentulous mandible.

<u>Conclusions</u>: This study, performed on 123 human edentulous dry bone specimens, indicates that the edentulous arch and the residual ridge take many forms. At the occlusal surface of the edentulous jaw a trabecular track is the remaining scar after tooth extraction. To accommodate an entire metal osseointegrated implant within the residual bone volume, crest reduction and bone grafts may be required as preprosthetic surgical measures. After tooth loss, maxillary resorption was centripetal and apical, whereas mandibular resorption was centrifugal and also apical, resulting in a reversed horizontal relationship in fully edentulous subjects.

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INDEX WORDS: bone morphology, edentulous arches, residual ridges

REMOVABLE DENTURES and implantbased restorations are supported and retained by the edentulous structures: the residual bone

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Copyright © 2007 by The American College of Prosthodontists 1059-941X/07 doi: 10.1111/j.1532-849X.2006.00165.x ridges of the maxilla and mandible, the surrounding muscles, and the thin, soft-lining connective tissue and epithelium.¹⁻⁵ Consequently, it is primarily the bone tissue that provides the foundation and framework of the edentulous jaws for prosthetic use.

The contour of the bone tissue dictates the intaglio surface of the artificial removable prosthesis, whereas the muscle fibers attached to the external surfaces of the bony edentulous jaws determine the denture borders.^{2,4-6} Since osseointegrated implants are placed within the bone volume of the edentulous jaw, the external and internal bone morphology are of paramount importance for the outcome of the intended restoration. Furthermore, the angulation and direction of the bony residual ridge to the horizontal plane and the ridge relation to the occluding jaw must be known. This knowledge will help determine the placement and direction of the intended implant

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in a proper position with the adjacent teeth or implants. It may also help select a correct vertical relation with the teeth of the occluding jaw. Therefore, it is important to know and understand the bone morphology of the residual ridge in the regions of the edentulous jaws that support and stabilize a removable prosthesis and into which osseointegrated implants are inserted to provide the abutments for the planned restorations.

There is relevant but insufficient documented information regarding the form of the maxillary and mandibular edentulous jaws, residual bone type, and configuration of the edentulous jaws at the incisor, premolar, and molar regions.⁷⁻¹⁶

Specific residual ridge regions have been examined in one or both edentulous jaws.^{7-10,12,15} Cawood and Howell⁹ classified edentulous jaws based on a randomized collection of 300 maxillary and mandibular dentulous and edentulous jaws. They described anterior and posterior jaw regions and stated that the changes in shape of the alveolar process follow a predictable pattern after tooth loss.

The edentulous arches are vital structures present during the patient's life regardless of tooth presence or function. The residual ridge is formed following tooth extraction, and remodeled mainly by resorption. With time and wear, it could shrink and even disappear as an anatomic entity.¹⁷⁻²¹

An anatomic-morphologic description of a collection of fully edentulous dry maxillae and mandibles was not found in the literature. The purpose of this study was to examine the form and structure of the bony maxillary and mandibular edentulous arches as a whole and their residual ridges in the incisor, premolar, and molar regions in particular.

Materials and Methods

The sample consisted of consecutive, accumulated, or acquired 24 maxillary and 99 mandibular fully edentulous, 69 male, 46 female, and 8 unknown gender adult jaw specimens from the Department of Anatomy, Tel Aviv University. Specimens were completely edentulous with mature bone residual ridges at the place formerly occupied by the natural teeth. There were no visible signs of tooth sockets and/or the remaining bony alveolar process that indicate recent tooth extraction.

There was no available data as to age, time of extractions, and sequence of tooth loss. Specimens were examined by macroscopic observations, caliper measurements, and angular determinations. Linear mea-



Figure 1. Width of maxillary edentulous arch was determined between left and right edentulous crest at the end of tuberosities (Line A). Arch length was measured from incisal residual ridge crest to inter-tuberosity line at center of palate (Line B).

surements (in mm) of the edentulous jaws and residual ridges were taken with a caliper (Calipretto, Renfort Co., Hilzingen, Germany) and used as units to determine the size of the specimens.

The width of the maxillary edentulous arch was determined between the left and right edentulous crest on the posterior end of the tuberosities (Fig 1, Line A). The length of the arch was measured from the crest of the residual ridge at the central incisor region to the intertuberosity line at the center of the palate (Fig 1, Line B). The width of the residual ridge at the incisor, premolar, and molar regions was measured at the crest of the ridge.

The width of the mandibular edentulous arch was measured between the right and left angles of the molar regions' crests and the ascending ramus (Fig 2, Line A). The mandibular arch length was determined from the bony crest of the incisor region to the same molar region intersections at the center of the jaw (Fig 2, Line B).

For residual ridge determinations, the left sides of the edentulous maxillae and mandibles were divided into three quantitatively proportionate regions representing the incisor, premolar, and molar positions before their loss. The buccolingual width of the residual ridge crest in the maxilla and mandible was measured at the top of the left incisor, premolar, and molar regions. Maxillary and mandibular residual ridges were classified as flat-rounded when more than 2 mm in width, or thin knife-edged when less than 2 mm.

The inclination of the left maxillary and mandibular ridges was determined between the ridge crest and horizontal plane at the incisor, premolar, and molar regions with a goniometer (Asa Spa, Via Vallenzana, Posano, Italy). A 90° perpendicular angle was used as the baseline for measurements.



Figure 2. Width of the mandibular body arch was measured at the right and left molar region intersections with the ascending ramus (Line A). Arch length was determined from the central incisors' crest to the middle of the molar region intersections (Line B).

In eight specimens, the maxillary and the mandibular edentulous jaws belonged to the same individual. Jaws were hand related in centric position by using the relation of the left and the right mandibular condyles to their corresponding left and right maxillary temporal fossae. The noncontacting edentulous surfaces of the maxillary and mandibular arches were positioned parallel, for examinations. The bone midline, at both jaws, helped to confirm that jaw placement was at the centric relation of the specimen.

Assessments of the linear measurements and shape determinations were made by two authors (JP, BA) according to accepted methods.^{18,22-25} Calibrations produced almost identical results: a 96% correlation.

Results

There was an extensive range in sizes at the edentulous arches and residual ridges in the maxillary and mandibular jaws (Tables 1 and 2). The edentulous arches are well-defined vital bone structures. Residual ridges can remain as stable tissues or become completely resorbed. Advanced resorption

Table 1. Size of the Edentulous Arches (mm)

	Mean	SD	Range
Maxillary Ede	ntulous Arch		
Width	48	2.3	39-60
Length	47	3.1	40-54
Mandibular E	dentulous Arch		
Width	78	9.4	73-84
Length	61	8	53-67

encompasses the original alveolar process, and also part of the contiguous palate in the maxilla and the adjacent cortical plates in the mandible. Occasionally, the only remainder of the original position of the natural dentition and its alveolar process in the edentulous jaws is an irregular bony trace. The right and left halves of each edentulous jaw were similar but not identical. Differences in size and shape were also detected between homologous regions: knife-edged short ridges in one site with wide-rounded bony ridges at the adjacent area (Figs 1-6).

In the eight specimens with the edentulous maxilla and its corresponding mandible, the vertical spatial relation between the edentulous jaws was of the ridge crest border-to-border type (3 specimens) and reverse articulation type—the mandibular edentulous crest was external to the corresponding maxillary crest (5 specimens). This was seen at both the anterior and posterior jaw regions (Figs 7 and 8).

Maxillary Specimens

Edentulous maxillae were ovoid (65%), triangular (25%), or irregular (10%). The arch width ranged from 39 to 60 mm (mean 48 mm) and the length from 40 to 54 mm (mean 47 mm) (Table 1).

The width of the ridge crest varied from 1 to 7 mm (Table 2). Of the maxillary specimens, 22% had knife-edge ridges and 78% had flat-rounded ridges. Knife-edged ridge crests, 1-2-mm thick, appeared in 47% of the incisors and in 10% of the premolar and molar regions of the samples. In the additional specimens, ridge crests were flat or round in 53% in the incisor region and 90% in the posterior areas (Table 2). The residual ridge was formed by trabecular bone tissue, external to the cortical palatal vault (Figs 1, 3, and 4). Angulations at the incisor, premolar, and molar regions between the edentulous crest and the base of the skull varied from 65° to 84° (Table 3). Therefore, the maxillary edentulous crests were external to the cranial base except at the nasal spine and zygomatic process, where the residual crest was internal to both structures (Figs 3, 4, 7-9).

Mandibular Specimens

Mandibular arches were ovoid (77%), square (11%), or irregular (12%). The width of the

	Mean (mm)	SD (mm)	Range (mm)	Knife-edged (%)	Flat-rounded (%)
Maxillary Ridge*					
Incisor	3	2.5	1-6	47	53
Premolar	4	1.4	2-7	10	90
Molar	5	3.1	2-7	10	90
Mandibular Ridge	t				
Incisor	3	2.2	1-7	75	25
Premolar	7	3.0	1-16	38	62
Molar	9	4.0	1-18	15	85

Table 2. Width of the Residual Ridge Crest

*Measured in 24 edentulous skulls.

[†]Measured in 99 mandibles.



Figures 3 and 4. Occlusal aspect of two edentulous maxillae. The cortical bony palate is surrounded by a distinct tract of trabecular bony tissue. Notice different sizes and shapes between the arches and between the adjacent residual ridges of the same jaws.

mandibular body arch varied from 73 to 84 mm (mean 78 mm); length ranged from 53 to 67 mm (mean 61 mm) (Table 1). The width of the residual ridge crest extended from 1 to 18 mm (Table 2). In these specimens, knife-edge ridges were found in 75% of the incisor, in 38% of the premolar, and in 15% of the molar regions. Flat-rounded ridges were found in 25% at the incisor, 62% in the premolar, and 85% in the molar regions (Table 2, Figs 2, 5, 6, 10).

The lingual cortical plate, complemented at a slope lower gradient by the buccal plate, formed the knife-edged ridges (Figs 5, 6, 10). The flatrounded ridges were formed by the buccal and lingual cortical plates with trabecular bony tissue between the two layers (Figs 2, 5, 6, 10). An irregular trabecular bony tract was present at the occlusal edentulous surface from the right to the left retromolar region (Figs 2, 5, 6, 10).

The edentulous crest measured at the incisor, premolar, and molar regions was lingual to the mental protuberance anteriorly and to the mandibular base posteriorly. This lingual inclination of the crest to the mandibular base varied from 99° to 120° (Table 3, Figs 5–8, 10).

Discussion

The alveolar process, the cancellous and compact bony structure that surrounds and supports the tooth,¹⁹ develops with tooth eruption, functions with tooth activities, and resorbs following tooth loss. The extraction site fills with trabecular bone to form the residual bony ridge, which continues to remodel during the edentulous life of the patient,



Figure 5. Occlusal views of two edentulous mandibles. A stretch of trabecular bone tissue is present at the entire edentulous surface from the right to left retromolar region. The trabecular tract varies from a wide ridge surface (Fig 5) to a thin, sharp line (Fig 6) and is clearly different from the lateral adjacent cortical plates.

sustaining progressive resorption changes. It could even disappear as an anatomic entity. The edentulous arches will also undergo remodeling resorptive changes but will always remain stable, vital structures (Figs 1–6, 9, 10).

The large percentage (38%) of knife-edged ridges at the edentulous crest shows the need to diagnose and eliminate sharp edges before implant placement or prosthetic procedures. This may prevent painful denture pressure points at otherwise knife-edged borders, which could jeopardize the success of the dental treatment.



Figure 6. Occlusal views of two edentulous mandibles. A stretch of trabecular bone tissue is present at the entire edentulous surface from the right to left retromolar region. The trabecular tract varies from a wide ridge surface (Fig 5) to a thin, sharp line (Fig 6) and is clearly different from the lateral adjacent cortical plates.



Figure 7. Frontal and lateral aspects of edentulous jaws articulated at centric relation. Maxillary edentulous crest is external to the osseous base of the cranium, whereas the mandibular crest is internal to the base of the lower arch. This condition develops a reverse relation: the maxillary crest is internal to, or level with, the occluding mandibular crest in the anterior and posterior regions of the jaws.

The buccolingual width of the bony crest was 1 to 2 mm in 43% of all mandibular specimens and in 75% at the incisor region. The cervical diameter of the thinnest available osseointegrated implant is 2.7 mm. Implant protocols require the cervical implant neck to be completely embedded in the bony residual crest. The greatest stress of a loaded implant is around the implant neck and at the ridge crest.^{1,15,26-28}



Figure 8. Frontal and lateral aspects of edentulous jaws articulated at centric relation. Maxillary edentulous crest is external to the osseous base of the cranium, whereas the mandibular crest is internal to the base of the lower arch. This condition develops a reverse relation: the maxillary crest is internal to, or level with, the occluding mandibular crest in the anterior and posterior regions of the jaws.

	Mean	SD	Range
Maxilla*			
Incisors	73	3.9	65-84
Premolars	79	4.5	75-83
Molars	77	5.0	74-82
$Mandibles^{\dagger}$			
Incisors	109	5.5	99-120
Premolars	107	6.6	100-112
Molars	106	6.0	100-113

Table 3. Angulations (in deg) of the Residual Crest to the Base of the Edentulous Jaw

*24 measurements in each region.

[†]99 measurements in each region.

Consequently, to properly host the thinnest implant neck inside the bony surface, sharp bone reduction at the top of the residual ridge and/or bone grafts are often required. These surgical procedures will provide a proper wide bony crest at the expense of a shorter ridge to host the entire length and width of the planned implant.

Size and the inclination of the residual bony crest to the horizontal edentulous plane are different in each case. This makes computerized tomography imperative to determine the size and the angulation of each intended osseointegrated implant.

In both jaws, the resorption pattern following tooth extraction is mainly at the expense of the alveolar process. The maxillary osseous base is internal to the original tooth position, and as a



Figure 9. Lateral view of a highly resorbed edentulous maxilla. Bone irregularities and knife-edges are present at the edentulous crest surfaces. The crest of the edentulous arch is external to the osseous base of the cranium. Nasal spine (N).



Figure 10. Lateral view of an edentulous mandible. The anterior bone ridge crest is formed by the higher lingual cortical plate and the lower buccal plate with trabecular bone between them. Ridge crest is lingual to the base of the mandible.

result, the maxillary bone resorption that follows tooth loss is centripetal and apical. This results in an edentulous maxilla that is narrower and shorter than the original dentulous arch.

In the mandible, the base of the bone is external to the natural teeth. After tooth loss, migration of the mandibular residual crest is centrifugal and apical, towards a wider and shorter edentulous mandible.

This discrepancy is responsible for the virtual "shrinkage" of the maxilla, the "expansion" of the mandible and the border-to-border or reverse occlusal relation of the residual crests, as detected in fully edentulous patients^{4,5,12,15,21,29,30} (Figs 7, 8). This situation requires the attention and decision of the clinician, the dental technician, and the patient—where to place the artificial teeth at the vertical plane and whether to select an Angle's Class I occlusal relation, an edge-to-edge, or reverse articulation.

Conclusions

The edentulous structure takes many forms. The trabecular track present at the occlusal surface of the edentulous jaw is the bony scar tissue that remains after tooth extraction. Of all the examined residual ridge crests, 38% were thin knife-edged, less than 2 mm in width. To produce a round, painless bony surface, surgical crest reduction and/or bone grafts may be required. These procedures provide a wider bony crest at the expense of a shorter ridge to host the entire width

of an implant's cervical neck and/or to properly support a removable denture. After tooth loss, maxillary resorption is centripetal and the edentulous maxilla is apical and palatal to the original dentulous arch. In contrast, the apical migration of the edentulous mandible is centrifugal, resulting in border-to-border or a reverse-arch relation in fully edentulous individuals.

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