Otic axis locator: Closing the accuracy gap in cephalometrics and cast mounting

Raymond C. Thurow, DDS
Verona, Wisc

An overview is presented of a new technique to improve the accuracy and reproducibility of earpost-dependent orientation in procedures such as cephalometric radiography and cast mounting, using a custom-molded ear canal insert to provide a stable fitted socket for more exact earpost fit. This is especially valuable in follow-up treatment and serial studies because the insert can be filed for future use on the same patient to provide identical positioning in successive registrations. Cephalometric radiography is further enhanced by the addition of a radiopaque x-ray marker deep in the canal, otherwise inaccessible, close to the bony ear canal (anatomical porion) and the mandibular condyle. This marker is also visible in all 3 cephalometric views—lateral, frontal (posteroanterior) and coronal (submental-vertex)—providing an exact common horizontal axis (Otic axis) for a three-dimensional Cartesian coordinate system of measurement. (Am J Orthod Dentofacial Orthop 2000;117:298-302)

B. Holly Broadbent's vision of the future of cephalometrics, when he introduced it to the profession in 1930,[1] did not include its current widespread use in orthodontic diagnosis. He saw it only as a research tool for pooled serial growth studies encompassing three dimensions, using the "frontal" (posteroanterior) view in combination with the lateral view. The x-ray measurement system was patterned after craniometrics, an anthropometric technique for measuring dried skulls by using an instrument called a craniostat to orient, hold, and measure the skull.

The first step in orienting a skull is to suspend it by the most obvious bilateral structures, the ear holes (external auditory meati). These openings appear ready-made for that function. Gently inserting the movable earpost tips of the instrument as far as possible gives a very accurate, reproducible position. The contact point where the earpost engages the superior surface of the opening has been termed *porion*, and the axis connecting the right and the left porions is the baseline for most orientation and measurement.

Rotation around the earpost axis is then adjusted to place the inferior margin of the left orbit (orbitale) on the same level as the porions to establish the *Frankfort horizontal plane*, which is the generally accepted horizontal reference plane.

Broadbent adopted this same orientation for the cephalometric radiography of living patients. His head holder was a modified craniostat positioned with one x-ray generator exactly aligned with the earpost axis and another perpendicular to that axis. Channels to hold film cassettes were mounted on the craniostat perpendicular to each x-ray beam to complete the major modifications.

His description of patient orientation is simple:

> Like the relation of the skull to the cephalostat, the head rests on the uppermost sides of the rods that are inserted into the ear holes....After the head has been centered, the chair is lowered or the child instructed to settle down so that the under surfaces of the superior border of the ear holes are resting on the upper sides of the ear rods. Then the head is rotated on this Porion axis by lifting or lowering the face until the lowest point on the inferior bony border of the left orbit is at the level of the top of the ear supports as indicated by the Orbital marker.

He goes on to describe the final step of "Placing this (Nasion) rest against the root of the nose clamps the head firmly in the instrument."

The top of the soft tissue ear hole is called porion and is treated the same as the underlying bony structure, despite the obvious differences imposed by the interposition of mobile soft tissue. The loose-fitting movable serpentine cartilaginous ear canal displaces the earpost laterally about 2 cm and introduces wide parasagittal variability that leaves the porion wandering from film to film.

That relocation and resulting variability of the cephalometric porion is well known but generally ignored in clinical application, being viewed as an unavoidable variable that can be only moderately controlled.[2-4] This is inconsequential in typical cephalometric diagnosis based on lateral cephalomet-

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Reprint requests to: Raymond C. Thurow, DDS, 8058 Coray Ln, Verona, WI 53593-9072; e-mail, www.thurowrc@chorus.net

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ric films, because significant decisions do not turn on the several millimeters or degrees of variability involved, but the reliability of the porion can be critical in our evaluating individual serial changes or precise functional occlusal orientation.

Ricketts[5] has repeatedly called attention to this problem and recommends use of the x-ray image of the bony aperture in the lateral view, instead of the top of the earpost. This is an accurate landmark, which makes use of the original porion of craniometrics, but the difficulty of locating it consistently and identifying right and left on typical clinical films has limited its usefulness and wider adoption. Like most landmarks, it is also identifiable on only one x-ray view, further limiting its applicability in three-dimensional studies.

Earpost Orientation of the Living Head

Broadbent does not indicate how far he inserted the earposts, merely describing the objective of centering the head by using scales on the earposts before further stabilizing with the nasion rest. The ear canals are highly variable among individuals, irregular in shape and both flexible and sensitive. Those anatomic characteristics make it impossible to engage a canal with the consistent accuracy required for precise orientation, measurement, or reproducible positioning. Broadbent tacitly recognizes this when he notes little change in some cranial base areas and recommends superimposing their images for serial evaluations.

Earposts for ear canal engagement have been fabricated in endless variations of cylindrical, conical, and bulbous forms. The technique of their insertion has also been varied in many ways in attempts to improve consistency and accuracy, but significant improvement continues to elude us.

At one end of the earpost spectrum are the bulbous forms, which are often used on face-bows for cast mounting. This is usually not intimidating to the patient because the mechanism is not very threatening and the earposts engage the external auditory meatus at the least sensitive outer opening. That is also the largest and most mobile part of the canal, so the technique must be aimed at minimizing tissue distortion as the face-bow is adjusted and finally locked into position. The operative word in the statement above is “minimizing,” because even a highly skilled operator must contend with the inevitable variability of final earpost position.

At the other end of the earpost spectrum are the small, sometimes tapered shapes intended for the deeper insertion needed to optimize accuracy in cephalometrics. The cephalostat mechanism that closes the 2 earposts toward each other facilitates deeper insertion, and tissue distortion becomes an essential objective to enable insertion into the smaller, deeper part of the canal. This coordinated insertion of both earposts is a trying procedure for both operator and patient. While the operator is trying to insert the earposts uniformly to maximum depth with the head perfectly oriented, the patient is responding predictably with unpredictable avoidance moves. The lining of the canal is progressively thinner and more sensitive as the earposts move inward. When the operator feels that the earposts are inserted as far as possible, a final instruction to close the teeth together and hold still can cause yet another shift as the condyle intrudes on the already tight space just before the x-ray exposure.

Predictably, exact alignment of both sides with any of these techniques is even more rare than a hole in one. Taking another film or making another face-bow registration with the same orientation is virtually impossible. Even successive films exposed without removing the earposts can be expected to show different positions. This is easily seen in the placement of the images of bilateral structures on individual lateral cephalometric films, as well as by superimposing successive films over each other. Face-bow registrations can be compared by mounting a pair of casts and then remounting only the upper cast while using a new registration.

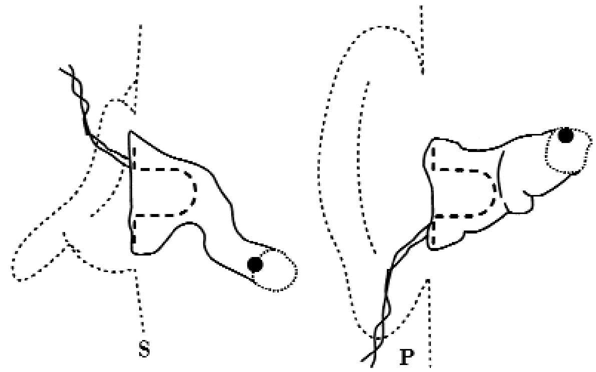

Fig 1. Superior *(S)* and posterior *(P)* views of left earmold impression showing canal form, earpost socket liner, and x-ray marker.

Ear Canal Anatomy

A close look at the anatomy of the ear canal will show why the many variations in earpost form and management have failed to solve the competing problems of accuracy and comfort. Fig 1 shows the irregular shape of a left ear canal in superior and posterior views of a full-size impression of the outer portion of the canal. The most movable part of the sound conduction system is the concha of the external ear which collects sound and

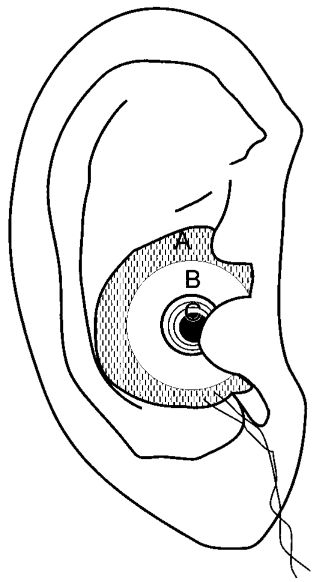

Fig 2. Earmold impression *(A)* with socket insert (flange *[B]* and socket *[C]*).

directs it toward the funnel-shaped aperture of the canal. The tragus partially hides and protects the opening, and the canal continues directly inward from there. Below the overlying skin and cartilage, it makes a sharp posterior, and slightly upward, turn. That first turn is as far as we can see in most cases without instrumentation, and it is also as far as a bulbous earpost can penetrate. The canal extends inward a long way from there, and as soon as there is room for another turn, it turns more inward and slightly upward as is passes behind the mandibular condyle. It then turns more inward after another short run and becomes smaller and more round as it enters the temporal bone and continues on toward the eardrum in a posteromedial direction. The turn behind the condyle is as far as a conventional earpost can be expected to penetrate because the canal is coursing at a significant angle, while the earpost is pointed medially.

The proximity of underlying cartilage and bone progressively decrease mobility, while the sensitivity of the lining of the canal increases as it courses inward toward and through the bony entrance into the skull. The external third of the canal is surrounded by cartilage and other soft tissue, but beyond the osteo-cartilaginous junction behind the medial part of the condyle, its character changes. The lining within the temporal bone is thinner, devoid of glands and hairs, and much more sensitive[6]. Fig 1 shows how the cross-section of the canal progressively diminishes from a large flattened ovoid to a much smaller round shape as it progresses into the bone.

The wide individual variation in the deviant course and changing cross-section of the canal make accurate engagement with any earpost design an unattainable objective. Off-the-shelf earposts can be expected to fit no better than off-the-shelf dentures. Clinicians have always been aware of these problems, which are responsible for countless adjustments of dental devices fitted to articulators and continue to limit the utility of cephalometric measurement to applications that can tolerate the large variations.

Anatomical X-ray Landmarks in Cephalometrics

Orienting the head is just the first of the two functions of ear canal engagement in cephalometrics. The other is to provide a bilateral pair of anatomical reference points at or near the temporomandibular joint to establish a transverse axis for orientation and measurement of x-ray images. This is the primary axis for the same Cartesian coordinate system of three-dimensional orientation and measurement long used in craniometry. If we had the same access to the bony canal as the physical anthropologist does in measuring dried skulls, this whole discussion would be irrelevant, but no such solid engagement is available on a living head. Nor are there any anatomical points that we can consistently identify for a transverse axis on any x-ray view.

Radiopaque markers are the only alternative. Implants in bone are out of the question in human subjects today, so we must rely on removable radiopaque markers. A marker attached to the earpost has always served this purpose in cephalometrics, but for reasons already discussed, they bear such a loose relationship to underlying anatomical structures that they are useless for accurate measurement. They also lie so far outside of the underlying bone structures that they are sometimes lost outside the edges of the image area of the film on frontal and coronal views.

A NEW SOLUTION

The objective of the otic axis locator described here is to significantly reduce the long-accepted level of variability by enhancing the reliability of ear canal engagement and, thus, raise the accuracy of dependent procedures to a new level. A molded ear canal insert flexible enough to allow for easy removal and reinsertion reshapes the entry to the large irregular canal with an integral socket designed to accurately receive the earpost of the cephalostat or face-bow. A pair of these ear canal inserts provide a degree of accuracy in positioning and reproducibility unachievable with conventional methods, while also improving patient comfort. Both the exact positioning of the earpost and the added stability provided by the close fit throughout the ear canal contribute to the accuracy of positioning.

Forming the socket directly in the earmold insert is adequate for face-bow orientation, but incorporating a rigid radiolucent flanged socket liner further improves stability and facilitates earpost insertion for cephalometrics, where the ear canal must control the entire head.

Cephalometrics also requires a radiopaque marker embedded in the insert to provide an x-ray reference point close to the condyle and the more stable bony canal. This places the marker close to the anatomical porion of craniometrics. To avoid compounding the confusion by adding yet another porion to the points already given that name, these markers are identified as *otic markers*. The axis connecting the right and the left otic markers is the *otic axis*. These markers provide the only stable landmarks that can be clearly identified in all 3 x-ray views, so the same otic axis can be reliably identified in all films for reliable and three-dimensional measurements and analyses.

Placing an Earpost Socket Liner

The primary alignment for accurate reproducible placement of earposts is provided by the socket that receives the earpost. Embedding a rigid radiolucent flanged earpost socket liner in the external face of the earmold impression adds rigidity and facilitates earpost insertion.

The socket liner is located to minimize distortion of the surrounding ear tissues. This may place it in a somewhat different position than the typical earpost that is forced through bends in the canal. The placement should be checked before mixing the impression material, so the flange can be trimmed as may be required to fit behind the tragus and accommodate any unusual anatomical variations. Final placement in the soft impression is facilitated by holding it with a lightweight bow similar to those used to hold paired earplugs or audio earpieces. The bow is stabilized by a simple earplug on the other side as it holds the insert in position while the impression material sets.

Placing a Radiopaque X-ray Marker (Otic Marker)

For cephalometric applications, a radiopaque x-ray landmark is inserted near the most stable inner end of the insert, close to the temporomandibular joint and the original anatomical porion. A metal ball about 2 mm in diameter is an appropriate marker for embedment or other secure attachment near the inner end of the impression. Right and left can be distinguished by placing double markers on the left or by using unique sizes or shapes on opposite sides. Two methods may be used for placing these markers:

1. One method is to attach it to the retrieval thread used on the impression blocker described below with the impression technique. Both thread and marker are inserted into a small section of heat-shrinkable tubing, placed against or inside of the blocker, and then secured by the application of heat to lock the tubing onto the blocker and thread. This provides a very secure attachment for the assemblage, which will become embedded in the impression. This has the advantage of single-stage fabrication, with the disadvantage that the exact location in the impression cannot be controlled.
2. For more exact positioning of the marker, it is inserted directly into the finished impression after it has been removed from the canal. A hole is made at the desired location, and the marker is then inserted and secured to prevent accidental dislodgement.

Impression Technique

The impression technique is a modification of the technique typically used in the fabrication of hearing aids that fit inside the canal,[7] with use of impression materials made for that purpose. These are typically silicone-based materials with an incorporated lubricant that facilitates removal from the dry lining of the canal.

Preparation for the impression is brief. First, the ear canal is examined with an otoscope to verify that there are no blockages, inflammation, or other abnormalities that might interfere with the impression. (These are uncommon and in most cases would also require modification or postponement of conventional earpost insertion.)

Next, the procedure is rehearsed so the patient knows what to expect and how to respond to instructions. The socket liner is positioned and the flange is trimmed if necessary. If a face-bow is being used to hold the socket, it is then placed on the bow and positioned with the bow. The patient is instructed to hold the teeth in occlusion as will be done later while the impression sets; dentists are already familiar with the intrusion of the lateral pole of the condyle on the canal in many individuals, as demonstrated by palpation, and the closing of the jaw ensures that the earmold will be formed to accommodate this movement. Finally, the liner assemblage is removed, and the patient is ready for the impression.

The first step in the impression procedure is placing a soft canal blocker, attached to a strong thread, into the ear canal at the desired depth, leaving the end of the thread hanging outside of the canal to aid in retrieval of the impression. This limits penetration of the impression material and can facilitate retrieval of the finished impression. Blockers are typically fabricated from cotton pellets or soft foam.

The impression material is then mixed, placed in a syringe, and immediately injected into the canal, beginning with full insertion of the syringe tip and then withdrawing it as the canal is filled. The area surrounding the opening of the canal is also filled, and the socket liner is immediately positioned in the soft impression material. The patient is then instructed to hold the teeth in occlusion while the material sets.

After the material has set, the impression is removed with the aid of the protruding thread. Setting times are, depending on the choice of impression material, around 10 minutes.

The impression on the opposite side can be made as soon as the first impression has set. These impressions are ready to use as soon as the material sets but must be removed for post-impression placement of an x-ray marker or to confirm appropriate positioning of a marker embedded in the impression at the time of molding.

Using the Otic Axis Locator

Use of these otic axis locators is simple, requiring little change in technique from current practice. Normal procedures are used after the inserts are fully reseated in both ear canals. For cephalometrics, there is a slight change in earpost placement because they should be tightened only enough to fully seat them; excessive tightening may distort the insert and cause unnecessary patient discomfort. The whole procedure after the inserts are placed is actually faster and more comfortable than conventional methods.

These inserts should be filed after use so that they are available later for follow-up films or other procedures. They can be re-inserted at any time after verifying that the canals are clear. The only reason for fabricating new inserts is alteration of the canals by growth, injury, or surgery.

SUMMARY

An otic axis locator consists of an earpost socket in a removable/reinsertable insert molded to fill the outer portion of the external auditory canal. This provides for greatly improved stability and accuracy in earpost placement, enabling a more accurate and consistent horizontal axis in the condyle area for mounting dental casts in articulators and for head positioning for cephalometric radiography. It also eliminates most of the pain, discomfort, and associated patient movement that typically occurs in positioning the head for cephalometrics.

Placement of a radiopaque marker near the inner end of the insert adds several important advantages for cephalometric imaging: (1) Locating the marker close to the bony ear canal provides maximum stability. (2) Locating the marker deep in the canal places it very close to anatomical (true) porion. (3) The same point can be identified in all three cephalometric views. (4) Its position close to the mandibular condyle facilitates the accurate relating of the temporomandibular joint to the rest of the facial skeleton. (5) The more medial location close to skeletal structures helps keep it from being lost off the edge of the image area in frontal and vertical views.

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