Universidad Europea

TRABAJO DE FIN DE GRADO

Grado en Odontología

ESTRUCTURA Y DESARROLLO DE LA MANDÍBULA: LA MASTICACIÓN QUE NOS PERMITIÓ OÍR

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RESUMEN

Introducción: la evolución de la mandíbula y del oído, la estructura de la articulación temporo-mandibular y sus alteraciones han sido estudiadas. Además de la capacidad de propagación del sonido a través del hueso y a la diferencia entre los implantes osteointegrados y el nuevo sistema SoundBite.

Objetivos: han sido fijados con la idea de explicar la relación entre la mandíbula y el oído y sus consecuencias.

Metodología: para alcanzar los objetivos se ha realizado una revisión bibliográfica utilizando base de datos como Medline, Pubmed, Access Medicine y unos libros de texto adicionales. Las palabras claves empleadas han sido mandíbula, embriología, *tinnitus,* oído, articulación temporo-mandibular, conducción ósea del sonido, sistema SoundBite.

Discusión: El propósito de este trabajo de fin de grado ha sido estudiar el tipo de relación existente entre la mandíbula y el oído medio en el curso de la evolución humana. Sucesivamente la atención se ha enfocado en los posibles trastornos que pueden desarrollarse como consecuencia de la estrecha relación entre estas dos estructuras anatómicas y como, posibles alteraciones en una pueden llevar a tener consecuencias en la otra. Se ha descrito la influencia que estas alteraciones pueden tener en un individuo, condicionando el curso normal de su vida.

Además, se ha investigado la capacidad que el sonido tiene de propagarse a través del hueso mandibular y elementos dentarios. También se ha estudiado la diferencia entre la propagación del sonido a través del hueso y del aire, describiendo los primeros implantes auditivos osteointegrados hasta llegar a los últimos avances tecnológicos con el sistema SoundBite.

Conclusiones: la mandíbula y el oído han evolucionado juntos, condicionando el desarrollo de alteraciones en ambas estructuras. Por otra parte, esto ha permitido que las vibraciones sonoras se propagaran a través del hueso y se ha llegado al desarrollo del sistema auditivo SoundBite.

ABSTRACT

Introduction: the evolution of the mandible and the ear, the structure of the temporomandibular joint and its alterations have been studied. The ability to propagate sound through bone and the difference between osseointegrated implants and the new SoundBite system.

Objectives: the objectives have been fixed with the idea of explaining the relationship between the jaw and the ear and its consequences.

Methodology: a bibliographic review has been carried out using databases such as Medline, Pubmed, Access Medicine and additional textbooks. The keywords used were jaw, embryology, *tinnitus,* ear, temporomandibular joint, bone conduction of sound, SoundBite system.

Discussion: the purpose of this final thesis has been to study the type of relationship between the jaw and the middle ear in the course of human evolution. Successively, attention has been focused on the possible disorders that may develop as a consequence of the close relationship between these two anatomical structures and how possible alterations in one can lead to consequences in the other. The influence that these alterations can have on an individual have been described, conditioning the normal course of his life. In addition, the ability of sound to propagate through the mandibular bone and dental elements has been investigated. The difference between the propagation of sound through bone and through the air has also been studied, describing the first osseintegrated hearing implants up to the latest technological advances with the SoundBite system.

Conclusions: it has been concluded that the jaw and the ear have evolved together, and this has conditioned the development of alterations. On the other hand, this fact has allowed sound vibrations to propagate through the bone and has led to the development of the SoundBite hearing system.

INDICE

INDICE DE FIGURAS

1. INTRODUCCIÓN

La evolución de la mandíbula y consecuentemente la del oído medio de los mamíferos es uno de los acontecimientos más importantes en la historia de los vertebrados ya que contribuyó al abastecimiento de los recursos necesarios para la supervivencia y a que el organismo se adaptase fácilmente a las condiciones ambientales. El sistema de audición (oído medio) progresó a la vez que la mandíbula ya que ambas estructuras se encontraban íntimamente asociadas. Una de las características que define a los mamíferos es la de tener tres huesecillos en el oído medio (1). Los reptiles y las aves solo tienen un huesecillo, el estribo o la columela. La forma en la que estos huesecillos llegaron a integrarse y funcionar en el oído medio de los mamíferos se ha estudiado durante los últimos 200 años y representa un clásico ejemplo de como las estructuras pueden cambiar durante la evolución para funcionar de forma novedosa (1).

1.1 La articulación temporo-mandibular

La articulación temporo-mandibular (ATM) es una articulación sinovial compuesta por el cóndilo mandibular y la fosa glenoidea del temporal. Existe una cápsula de tejido conectivo circundante, recubierta por una membrana sinovial, que segrega liquido sinovial lubricante, y está unida a músculos y tendones (2). Unido a la cápsula, y colocado entre el cóndilo mandibular y la fosa glenoidea está ubicado el disco articular. Las superficies sinoviales tanto de la fosa como del cóndilo están formadas por periostio fibroso. Existen tres capas de fibrocartílago amortiguador, en el disco y en las áreas sub-articulares del cóndilo de la fosa mandibular. La ATM es un tipo de articulación bilateral móvil de la mandíbula, un hueso muy evolucionado para acomodar una variedad de funciones respiratorias, masticatorias y de comunicación. Se puede argumentar que la mandíbula tiene una mayor influencia en el acervo genético humano que cualquier otro hueso del cuerpo [(3)].

Las anomalías y los traumas en mandíbula y articulación temporo-mandibular (ATM) pueden interferir con las funciones de soporte vital y a menudo se manifiestan como síntomas de desorden cráneo-mandibular incluyendo dolor del oído y *tinnitus.*

Los pacientes que presentan los típicos síntomas de trastornos temporo-mandibulares (TTM) suelen sufrir un cuadro de inhabilidad psicológica y física, limitación funcional, sueño alterado, que representan un conjunto de factores que influyen en una disminución de la calidad de vida [(4)].

El origen evolutivo de la ATM está íntimamente conectado con el de los huesos del oído medio. Los mamíferos tienen tres huesos del oído medio: el martillo, el yunque y el estribo. Los reptiles y las aves solo poseen un hueso en el oído medio que es homólogo al estribo de los mamíferos. Reichert et al. en 1837 propuso que los dos huesos adicionales del oído medio de los mamíferos eran homólogos al cuadrangular de la articulación de los no mamíferos. Gaupp et al. en 1912 amplió este concepto describiendo el desarrollo de una articulación primaria de la mandíbula entre el martillo y el yunque, y una articulación secundaría de la mandíbula, única para los mamíferos, entre el hueso escamoso (Figura 1) y dentario (Figura 2). Esta interpretación de la evolución de la mandíbula se ha apoyado gracias a la evidencia del registro fósil y a los estudios de desarrollo celular y molecular [(3)].

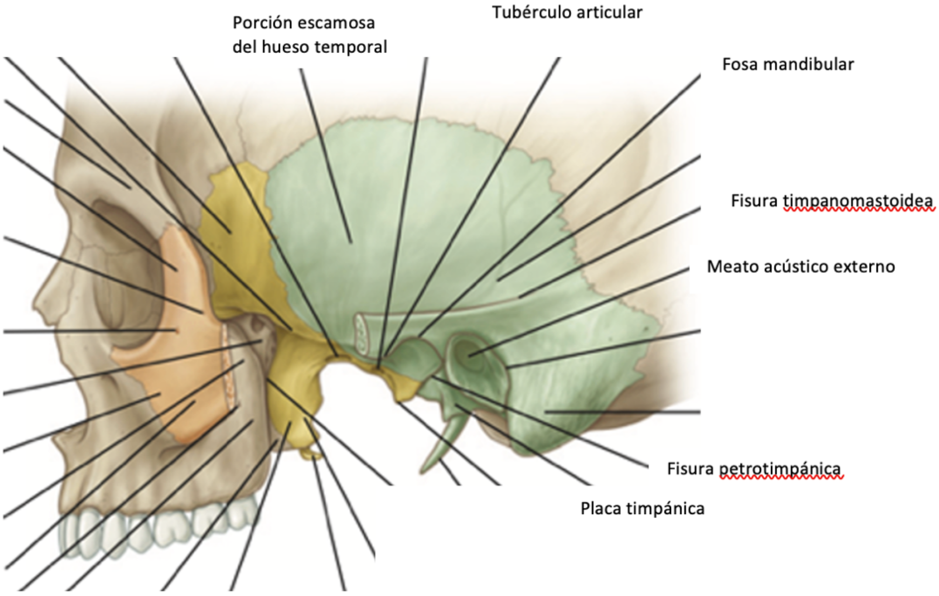

Figura 1

Visión lateral izquierda del cráneo, donde se puede observar el hueso temporal con sus porciones anatómicas. Imagen modificada de Drake R. et al. [5].

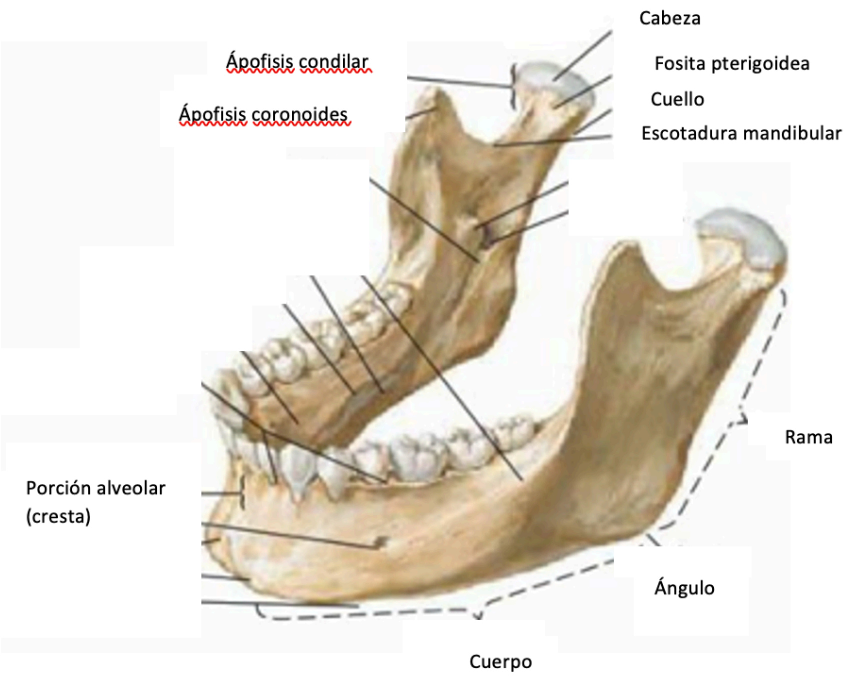

Figura 2

Imagen de la mandíbula con sus detalles anatómicos. Modificada de Netter [6].

1.2 Disfunción de la articulación temporo-mandibular (ATM)

Cuando se habla de trastornos de la ATM se hace referencia a un conjunto de problemas que involucran a los músculos masticatorios (Figura 3), a la propia articulación y las estructuras asociadas. El síntoma más frecuentemente asociado a estos trastornos es el dolor. La etiología se considera multifactorial, ya que varios factores como por ejemplo el bruxismo y factores psicológicos, pueden influir en su predisposición, iniciación y mantenimiento [7].

A B

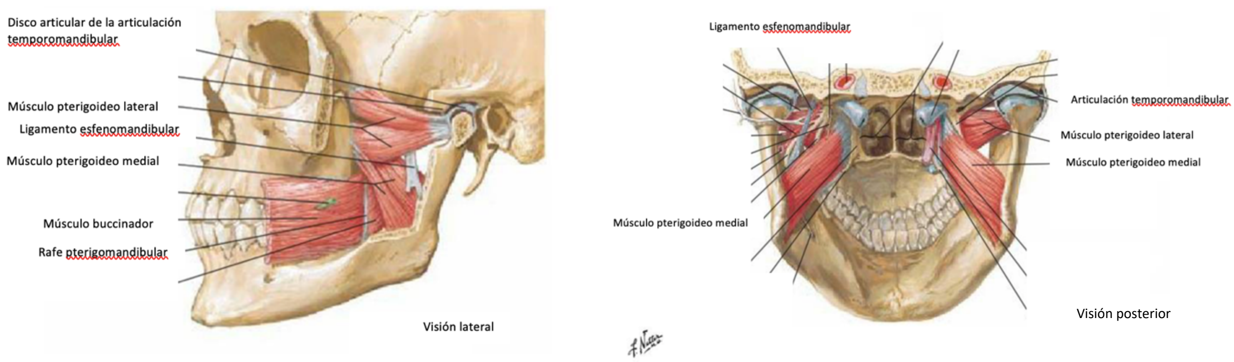

Figura 3

Visión lateral (imagen A) y visión posterior (imagen B) del cráneo donde se aprecian los músculos implicados en la masticación. Modificada de Netter [6].

La mayoría de estos trastornos, representados por el chasquido y la crepitación, se consideran como signos de alteraciones morfológicas, siendo indicativo el desplazamiento anterior con reducción discal. Contribuyen en el desarrollo de esta condición los desórdenes oclusales, la mordida profunda con insuficiente superposición horizontal, la actividad muscular inadecuada del musculo pterigoideo lateral y los contactos oclusales interceptivos en los dientes anteriores [8]. Se observa una proyección de la mandíbula hacia atrás. Esto produce una alteración morfológica en el borde posterior del disco y un alargamiento de los ligamentos que conectan el disco con el cóndilo. Durante el movimiento de apertura de la boca, el cóndilo se mueve hacia adelante y se desplaza sobre el borde posterior del disco hasta llegar a su parte central. En el momento del cierre de la boca, el disco se vuelve a desplazar produciendo un sonido atribuido al desplazamiento de los cóndilos en la zona retro-discal [8] (Figura 4).

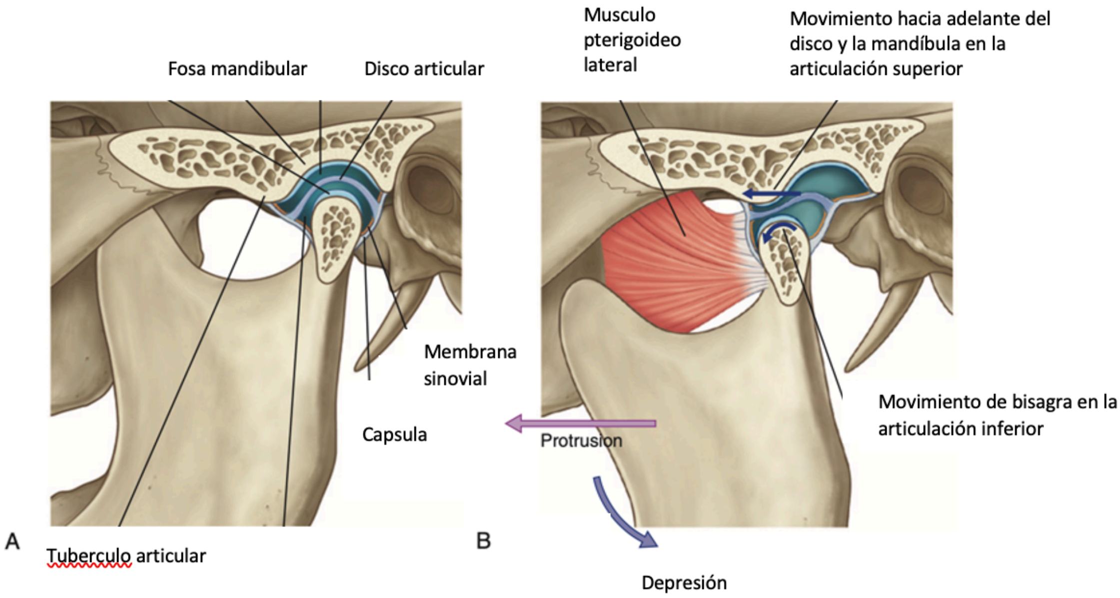

Figura 4

En la imagen A se puede apreciar la posición de la articulación temporo-mandibular y del disco articular mientras la boca esté cerrada. En la imagen B se observa la apertura mandibular con el respectivo movimiento del disco articular y del musculo pterigoideo lateral. Modificada de Drake R. et al. [5].

Asimismo, otro tipo de alteración que a menudo puede afectar a pacientes que presentan alteraciones de la articulación temporo-mandibular (ATM) es el *tinnitus*. Con este término se entiende la percepción de sonido en ausencia de un éstimulo auditivo externo. Los pacientes que padecen esta condición frecuentemente presentan trastornos psiquiátricos como ansiedad y depresión, además de problemas de audición, trastorno del sueño y de la concentración, interrupción de las actividades de la vida cotidiana, irritación y molestias [(9)(10)].

1.3 Propagación ósea del sonido

La excitación de la cóclea durante la estimulación auditiva por conducción ósea implica la transmisión de vibraciones a lo largo de los huesos del cráneo hasta el hueso temporal petroso. Los dientes representan otros elementos a través de los cuales se obtiene excitación de la cóclea [(11)]. Requieren una consideración especial los dientes del maxilar inferior, debido a que el único contacto entre la mandíbula y el cráneo tiene lugar por medio de la articulación temporo-mandibular (ATM) sostenida, como se ha explicado previamente, por ligamentos y rodeada por una cápsula llena de líquido sinovial. Por lo tanto, el tejido blando y el líquido sinovial son los encargados de realizar la unión entre dientes y mandíbula al cráneo y hueso temporal petroso. En comparación con la estimulación transcutánea, la propagación de las vibraciones sonoras a través del hueso proporciona umbrales asistidos mejorados y mayor rendimiento auditivo [(12)].

1.4 Audífonos osteointegrados *versus* sistema SoundBite

En 1981, Tjellstrom et al. proporcionó uno de los primeros informes clínicos sobre el uso de implantes de titanio osteointegrados en el hueso temporal, más tarde conocidos como audífonos anclados al hueso. Se trata de un tipo de implantes utilizados para permitir la conducción ósea de las vibraciones sonoras al hueso temporal. A partir del 1977 muchos han sido los estudios desarrollados que han permitido demonstrar que la tasa de supervivencia de este tipo de implantes a largo plazo varia entre el 81,5% y el 98,4%. En el curso de los años los diseños de estos implantes han evolucionado hasta llegar a tener diámetros más amplios, gracias también a las ventajas de los implantes dentales conocidas en odontología. Desde un punto de vista biomecánico la utilización de implantes dentales más anchos permite una mejor distribución de las fuerzas y mayor cantidad de hueso al que agarrarse. Sin embrago en odontología el uso de implantes anchos es limitado, ya que está condicionado por la anchura del hueso cortical y por los requisitos estéticos (13) (14).

La estimulación del oído interno, a través del sonido conducido por el hueso, produce una sensación auditiva utilizando mecanismos diferentes con respeto a la conducción de sonido por el aire a través del canal auditivo y el oído medio. Para calcular la potencia de transmisión a través del hueso se ha realizado un modelo de simulación. Se trata de un modelo tridimensional de cabeza humana, realizado por Chang et al. en 2016. La reconstrucción se ha llevado a cabo siguiendo la anatomía de la cabeza de una mujer adulta utilizando el programa *Visible Human Project*. La excitación se genera en la mastoides utilizando un tornillo que simula un audífono osteointegrado. Los resultados se compararon con estudios realizados en cabezas de cadáveres o en seres humanos vivos (15).

Recientemente se ha desarrollado una alternativa a estos implantes osteointegrados. Se trata de un dispositivo llamado SoundBite, capaz de conducir el sonido a través de hueso y dientes sin necesidad de una implantación en el interior del hueso.

Aclarados algunos conceptos, en las siguientes hojas se desarrollarán unos objetivos, establecidos con la intención de ilustrar la importancia que ha tenido, y sigue teniendo, el desarrollo de la mandíbula de la mano del oído en el curso de la evolución humana. Será igualmente relevante detallar la estrecha relación entre estas dos estructuras anatómicas que ha contribuido al desarrollo de diferentes alteraciones que han condicionado la vida de muchas personas. También se pretende demostrar la capacidad que tienen las vibraciones sonoras de moverse a través de estructuras como la mandíbula y los dientes y los importantes avances tecnológicos que ha habido gracias a este descubrimiento.

2. OBJETIVOS

Con la elaboración de este trabajo se pretende conseguir un objetivo principal y tres secundarios que se explicarán a continuación:

El objetivo principal:

1. Relación de los trastornos de la articulación temporo-mandibular con el oído: alteraciones en la cavidad bucal que implican patologías de la estructura del oído y/o viceversa.

A partir de allí se van a desarrollar tres secundarios:

2. Demostrar la posibilidad de propagación del sonido a través del hueso mandibular y elementos dentarios. Últimos avances tecnológicos: sistema SoundBite.

3. Explicar la evolución de la estructura de la mandíbula y del oído a lo largo de la evolución hasta llegar a su conformación actual.
4. Consecuencias en el comportamiento en pacientes con alteraciones de la articulación temporo-mandibular/tinnitus.

3. METODOLOGÍA

Para el desarrollo de este trabajo, basado en una revisión de la literatura científica inherente a la temática analizada, se han establecido algunos criterios de inclusión como, por ejemplo, que el texto seleccionado fuera completo. Por otra parte, se han ido excluyendo las fuentes que no permitían consultar su contenido de manera integra. Se han analizado estudios en idioma inglés y español con restricciones de fecha para que esta revisión sea lo más actualizada posible, salvo para algunos conceptos por los cuales se eligieron artículos publicados en fechas anteriores. La búsqueda se ha realizado a través del portal digital de la biblioteca "CRAI Dulce Chacón" de la Universidad Europea de Madrid, utilizando base de datos como Medline, Pubmed y Access Medicine. Adicionalmente han sido empleados los siguientes libros de texto: "Atlas de anatomía humana" del autor F.H.Netter, 5° edición, "Ten Cate's Oral Histology : Development, Structure, and Function" del autor Nanci A. y "Anatomy and Physiology of the ear" de los autores Oghalai JS y Brownell WE. Para la realización de este trabajo se han seleccionado 32 citas bibliográficas. Las palabras claves utilizadas para la búsqueda han sido:

- Mandible (mandibula): los textos obtenidos han sido de diferentes campos anatomía, fisiología y patología. Con este termino la búsqueda era centrada a una estructura concreta.

- Embryology (embriología): la necesidad de entender el origen de esta estructura requirió la búsqueda de textos sobre el desarrollo fetal de la mandíbula, así como de textos evolutivos.

- Tinnitus: se ha investigado acerca de las alteraciones presentes en el oído para entender su posible relación con la ATM. La búsqueda ha llevado a centrar el estudio en dicho termino en especifico.

- Ear (oído): se ha extraído información relativa a esta palabra a partir de textos de anatomía, fisiología y patología.

- Temporomandibular joint (articulación temporo-mandibular): la realización de la investigación utilizando esta palabra ha permitido el enfoque sobre estructura, desarrollo, funcionamiento y alteraciones de esta estructura determinada.

- Bone conducted sound (sonido conducido por hueso): la utilización de estas palabras ha permitido indagar de que manera se pueda conseguir la propagación del sonido a través del hueso mandibular.

- SoundBite system (sistema SoundBite): los textos obtenidos a partir de la búsqueda de información relativa a la propagación del sonido a través del hueso han llevado al hallazgo de la existencia de este sistema novedoso. La búsqueda se ha centrado en este termino en concreto.

4. DISCUSIÓN DE RESULTADOS

4.1 Evolución de mandíbula y oído

La evolución del aparato auditivo caracterizada, como se ha comentado previamente, por la presencia de tres huesecillos, está íntimamente conectada con la evolución de la articulación temporo-mandibular (ATM).

En la mandíbula de los vertebrados no mamíferos la ATM se forma entre los huesos cuadrangulares y articulares. En cambio, en los mamíferos se ha desarrollado entre los huesos escamosos y dentario. El hueso dentario ha ido aumentando de tamaño y la mandíbula ha pasado de tener siete huesos en los cynodontes pre-mamíferos hasta tener un único hueso en los mamíferos modernos. Paralelamente a esta transformación, algunos elementos de la articulación temporo-mandibular se han integrado a una cadena de huesos que han dado lugar al oído medio con una morfología capaz de detectar sonidos más sensibles [(16).]

En los mamíferos los huesecillos del oído medio crean una conexión entre el oído externo y el interno, y se encuentran en una cavidad llena de aire. La membrana timpánica vibra y estas vibraciones son recogidas por el manubrio del martillo, que transfiere la vibración del aire a los huesos yunque y estribo. Este a su vez conduce las vibraciones al oído interno a través de la membrana oval. El anillo timpánico es un hueso membranoso formado por la unión entre el martillo y el cartílago de Meckel (Figura 5) [(1)].

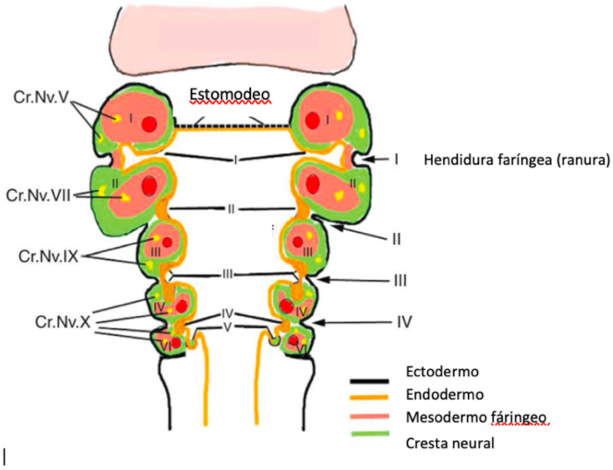

Figura 5

Arcos branquiales. Cada uno de ellos posee la misma estructura básica: endodermo (porción interna), ectodermo (porción externa), ectomesénquima (cuerpo central). El cartílago de Meckel corresponde al primer arco branquial. Imagen modificada de Nanci A. [17].

Siendo el más abundante tejido conectivo de la región craneofacial, el cartílago de Meckel nace a partir de un grupo de células neuroectodermicas de rápida proliferación y de células progenitoras derivadas del mesodermo y está presente en la mandíbula en desarrollo. Aparece como dos barras de cartílago hialino que atraviesan la parte lateral de la mandíbula (Figura 6) [18].

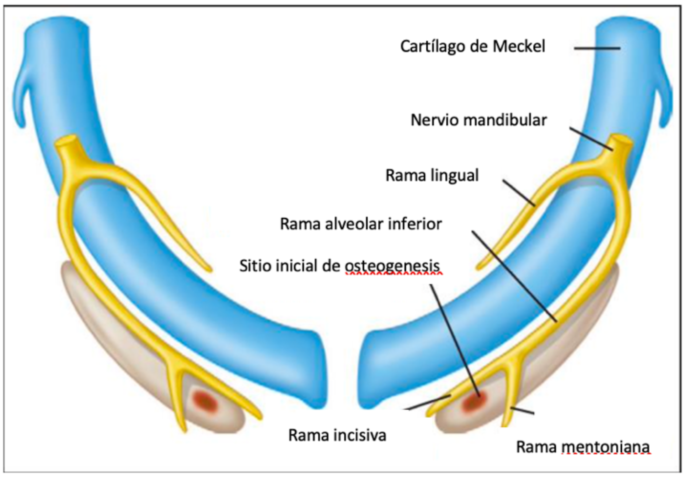

Figura 6

Cartílago de Meckel a la 6° semana de gestación, cuando se produce una condensación del mesénquima en el ángulo formado por la división del nervio dentario inferior en las ramas incisivas y mentonianas. A partir de esta condensación, en la 7° semana de gestación comienza la formación del hueso mandibular. Imagen modificada de Nanci A. (17).

Su desarrollo empieza con la agregación de células mesenquimales derivadas de la cresta neural craneal en la región molar. El cartílago de Meckel, además de su contribución en el desarrollo de la mandíbula, también juega un papel importante en la formación de los huesecillos del oído medio, la articulación temporo-mandibular y el paladar secundario.

En la mandíbula se extiende por una parte hacia la porción anterior y central (intramandibular) y por otra parte hacia la porción posterior, relacionada con el desarrollo del cóndilo mandibular y de la oreja(18) (Figura 7).

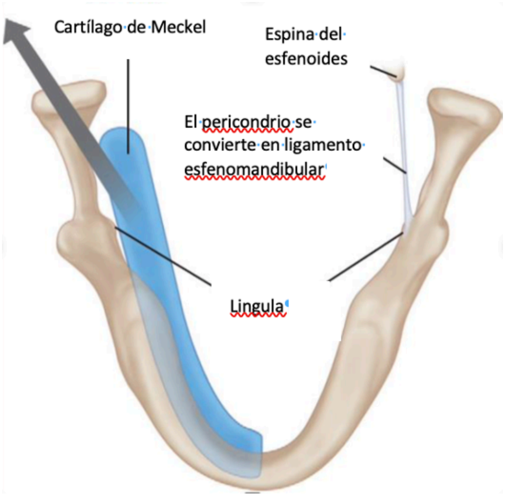

Figura 7

Osificación en el interior del mesénquima del primer arco branquial lleva a la formación de las ramas mandibulares, sustituyendo al cartílago de Meckel. Imagen modificada de Nanci A. [17].

Entre la semana 16 y 30 de gestación (4°-7° mes) la parte caudal del cartílago de Meckel se extiende hasta la oreja, dando lugar al martillo y al yunque a través de la osificación endocondral. Entre la sexta y la séptima semana se observa la primera osificación mandibular[18] (Figura 8).

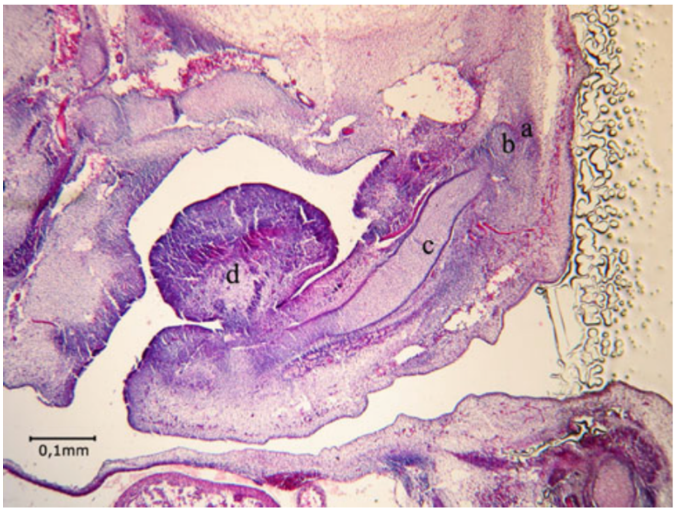

Figura 8

Sección frontal de un embrión en el día 46 (1 mes y 16 días).
a Primordio del disco articular y musculo pterigoideo lateral, *b* Primordio del proceso condilar, *c* Cartílago de Meckel, *d* Lengua [18].

En embriones de 19 mm (4° mes) se ve como el hueso se propaga desde el centro de osificación en la parte anterior del cartílago de Meckel. En embriones de 22 mm (4°-5° mes) se observa la formación de una mayor cantidad de hueso en la parte lateral del cartílago. A partir del día 51 de desarrollo (1 mes y 3 semanas) se puede ver en la región anterior todo el cartílago rodeado por la mandíbula[18] (Figura 9).

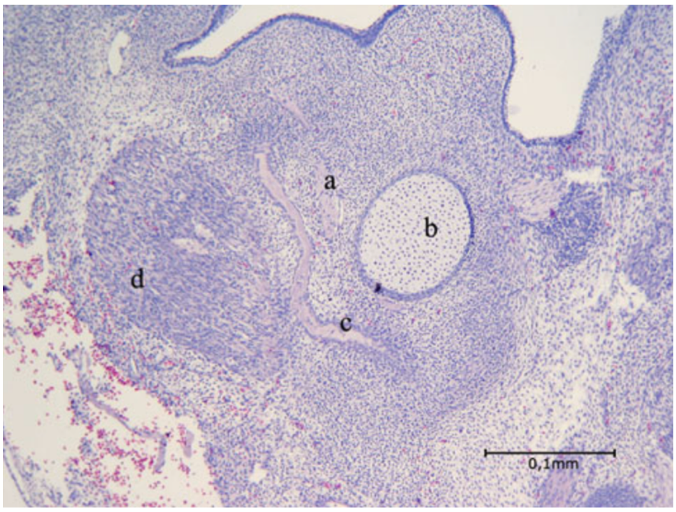

Figura 9

Sección transversal del embrión en el día 51 (1 mes y 3 semanas).
a nervio alveolar inferior, *b* cartílago de Meckel, *c* rama de la mandíbula, *d* musculo masetero [18].

La parte más proximal de Meckel en los vertebrados no mamíferos forma el articular y el cuadrado. Se trata de huesos endocondrales entre los que se forma la articulación de la mandíbula. La parte articular de Meckel y el cuadrado se derivan del primer arco faríngeo mientras que el proceso retro-articular y el cuerpo de la columnela derivan del segundo arco faríngeo. El cuadrado y el articular se originan de una condensación de cartílago que se subdivide para formar estos dos elementos esqueléticos separados por la articulación temporo-mandibular. También en el caso del martillo y del yunque se asiste a la formación de los dos huesos a partir de una única condensación de cartílago. El estribo, en cambio, se forma a partir de una condensación separada que crece hacia el yunque. El martillo y el yunque se forman en la parte posterior del cartílago de Meckel, como en el caso del articular y del cuadrado. Además, el martillo como el articular, durante la mayoría del proceso de desarrollo embrionario se queda unido al cartílago de Meckel, creando una conexión directa entre la mandíbula y el oído medio[1] (Figura 10).

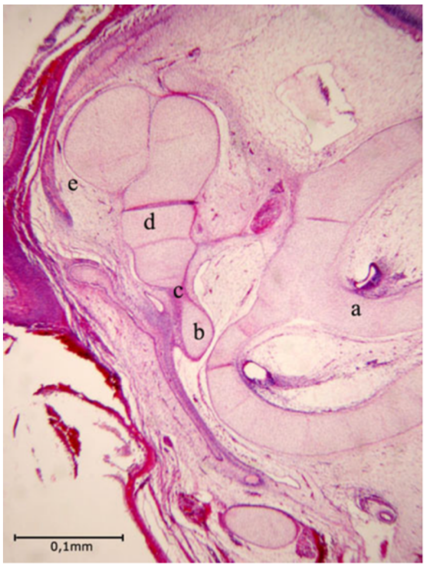

Figura 10

Sección transversal del feto.
a Laberinto, *b* cartílago de Meckel, estrechamiento entre el cartílago de Meckel y el martillo, *d* martillo, *e* cavidad timpánica [18]

Histológicamente se puede observar la unión entre el yunque y el *ala temporalis* a través de tejido conectivo. En los ratones la conexión de cartílago entre la mandíbula y el oído solo se rompe después del nacimiento con la transformación del cartílago de Meckel y del martillo en el ligamento esfenomandibular.

La ruptura del cartílago de Meckel en los mamíferos representa un paso importante hacia la formación del oído definitivo, porque permite la separación funcional entre el aparato masticatorio y el de la audición. En los seres humanos el cartílago de Meckel se rompe al octavo mes de gestación. Durante el desarrollo, el estiramiento de esta estructura cartilaginosa desde el primer molar hasta el martillo sufre una transformación y llega a formar una estructura fibrosa ligamentosa que se convierte en los ligamentos esfenomandibular y maleolar anterior.

El esfeno-mandibular participa en el desarrollo de la articulación temporo-mandibular limitando la distensión de la mandíbula y previniendo la dislocación; el maleolar anterior se une al martillo y a la pared anterior de la cavidad timpánica y actúa para estabilizar la mandíbula (1).

La mandíbula es el segundo hueso del cuerpo humano en osificarse, después de la clavícula. En la 6-7 semana de desarrollo intrauterino (2° mes) se desarrolla, en cada mitad de la mandíbula, un centro de osificación, que es la base para la formación del cuerpo y de la rama mandibular. En el periodo neonatal la mandíbula se compone de dos partes, unidas por la sínfisis mandibular que osifica en el primer año de vida. La mayor parte de la mandíbula se forma como tejido conectivo osificado, en la superficie lateral del cartílago de Meckel. En el tejido conectivo se va formando el cartílago que gradualmente comienza a osificar. El cartílago crece en el proceso corónide y cóndileo, en el ángulo de la mandíbula, en los extremos anteriores de ambas mitades de la mandíbula y en el arco dentario. Antes del nacimiento a la altura del mentón hay dos pequeños huesos que después del nacimiento se fusionan y crean la protuberancia mental. En el extremo posterior del cartílago de Meckel hay una conexión con la oreja; la osificación en esta zona lleva a la formación de dos huesecillos: el martillo y el yunque [19].

4.2 Conformación actual de la mandíbula

La mandíbula, también llamada maxilar inferior, a parte de ser el hueso facial más grande y resistente, es el único hueso móvil del cráneo, sin contar con los huesecillos del oído en el temporal. Observando desde un plano lateral, la mandíbula consta de una porción curva y horizontal, el cuerpo, y dos porciones perpendiculares, las ramas. El cuerpo y las ramas se unen en un área llamada ángulo de la mandíbula, donde se encuentra la tuberosidad del masetero, lugar de inserción del músculo que lleva el mismo nombre. En la parte medial de la rama se ubica el agujero mandibular, limitado anteriormente por la língula de la mandíbula. Aquí es donde se inserta el ligamento esfenomandibular. El borde superior de cada rama posee dos cóndilos, que se articulan con la fosa mandibular o glenoidea y el tubérculo cigomático anterior del temporal en la articulación temporo-mandibular. La mandíbula presenta una apófisis coronoides, en la que se inserta el músculo temporal. Entre la apófisis corónides y el cóndilo existe una depresión que se denomina escotadura del maxilar inferior. A la porción de hueso que contiene los alveolos de los dientes se denomina proceso alveolar.

La parte lingual (interna) del alveolo es mucho más gruesa que la vestibular (externa) [19]. La forma y el carácter de la mandíbula también están determinados por los músculos y ligamentos que se adhieren a este hueso. La estructura del hueso compacto es extremadamente densa y las láminas externa e interna son especialmente gruesas en la base de la mandíbula [20].

En su parte más anterior la mandíbula presenta el mentón, que en el curso de la evolución sufre numerosos cambios. De hecho, las mandíbulas prehistóricas se caracterizaban por una falta de barbilla. Esto ha ido cambiando a lo largo de la historia hasta que el mentón ha llegado a ser un rasgo marcado característico de los seres humanos, resultado de una diferente intensidad de crecimiento del cuerpo de la mandíbula y de la parte alveolar. Representa una adaptación general del cráneo, como consecuencia de un ensanchamiento de la caja cerebral, cambios en el ancho de la cara, hueso de mandíbula y paladar. La conformación actual de la mandíbula ha sido fuertemente influenciada por el logro de habilidades de comunicación que han llevado a un engrosamiento de la lengua y crecimiento mandibular [20].

4.3 Conformación actual del oído

El oído es un órgano complejo que tiene una doble función: permite percibir los sonidos (oído) y provee información acerca de la posición del cuerpo en el espacio (equilibrio). El oído humano está constituido por tres partes (Figura 11):

- Oído externo: formado por pabellón auricular y conducto auditivo externo. El primero consta de cartílago elástico recubierto por una capa de piel. La función del pabellón auricular es la de encaminar las ondas sonoras hacia el conducto auditivo. Este último está formado por una porción cartilaginosa lateral y otra ósea medial. El canal cartilaginoso anterior está formado por el trago. La mayor parte del conducto auditivo óseo está constituido por la porción timpánica del hueso temporal. En la porción anterior e inferior del canal auditivo se encuentran las fisuras de Santorini [21].

- Oído medio: anatómicamente, según su relación con el anillo timpánico, se divide en cinco partes: meso-tímpano, hipo-tímpano, ático, pro-tímpano y retro-tímpano. La cavidad del oído medio está conectado a la nasofaringe a través de la trompa de Eustaquio. Posterior a esta cavidad se encuentran las celdillas de aire mastoideas, que se conectan con el ático. Las células aéreas mastoideas y la cavidad del oído medio están revestidas con epitelio mucoso ciliado [21].
- Oído interno: las células más importantes del oído interno son las células ciliadas. Estas se encargan de convertir el estimulo mecánico asociado a la audición y al equilibrio en información neuronal para su transmisión al cerebro. El oído interno se divide en dos cámaras llenas de liquido. La externa contiene una solución de sal de sodio llamada perilinfa y la interna se llena con una solución salina con alto contenido de potasio, llamada endolinfa. La actividad de las células sensoriales está impulsada por la energía electroquímica proporcionada por la diferencia entre la perilinfa y la endolinfa [21].

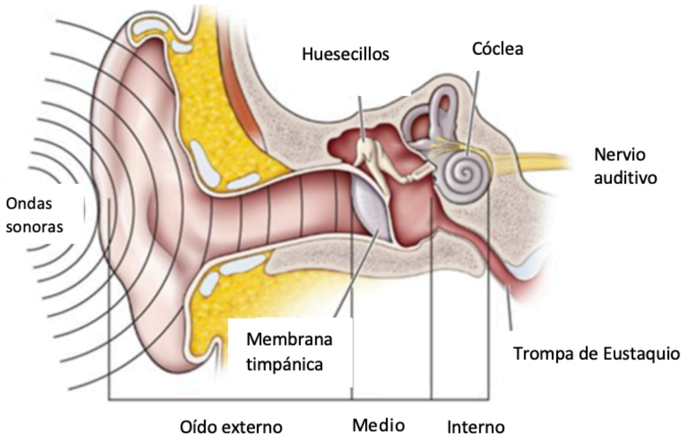

Figura 11

La imagen representa la anatomía del oído. Se puede apreciar como las ondas sonoras llegan al oído externo que las envía hacia la membrana timpánica. En el oído medio los huesecillos transfieren las sonidos a la cóclea (oído interno) [(21).]

4.4 Trastorno temporo-mandibular y alteraciones del oído

El término trastorno temporo-mandibular (TTM) incluye las alteraciones que afectan la articulación temporo-mandibular (ATM), músculos de la masticación y estructuras asociadas. Los síntomas que pueden estar relacionados a la ATM son ruidos articulares y bloqueo de la mandíbula con consiguiente limitación de la apertura bucal, dolor facial, de cabeza y mandibular. Aunque se consideren como síntomas importantes, también se clasifican como un síndrome. Se ha demostrado también la existencia de relación entre el TTM y problemas otológicos:

1. Otalgia
2. *Tinnitus*
3. Sensación de plenitud auricular
4. Disminución de presión auditiva
5. Hiperacusia

6. Vértigos
7. Mareos [22][23].

Con el término *tinnitus* se hace referencia a la percepción de un sonido, un silbido o zumbido, sin que haya ninguna señal acústica externa. Este tipo de ruido, que puede ser uni o bilateral, contínuo o intermitente, es debido a una activación de la corteza auditiva y hace que el paciente se sienta angustiado y enfermo. El *tinnitus* puede ser un síntoma de un trastorno otológico, como por ejemplo una infección del oído externo, otitis media u otosclerosis y síndrome de Meniere. También puede ser un síntoma de un trastorno neurológico, como neuroma acústico o **relacionado con trastornos de la articulación temporo-mandibular** [24]. Las estructuras del oído medio relacionadas con la mandíbula son varias y están inervadas por el nervio trigémino (V par craneal). Un excesivo funcionamiento del músculo masetero podría causar vibración y clonación en el músculo tensor del tímpano. En caso de espasmo esto causaría una insuficiencia del tubo auditivo. Una reducida aireación del oído medio predispondría el sujeto a padecer *tinnitus*, plenitud de oídos y dolor de cabeza [22]. Múltiples teorías han intentado explicar la asociación entre TTM y síntomas otológicos. En 1934 fue publicado el primer estudio de un otorrinolaringólogo inglés, J.B. Costen, que demuestra la relación entre los trastornos temporo-mandibulares y los síntomas otológicos. Hace más de 85 años, Costen introdujo el término "Disfunción temporomandibular". Para describir este síndrome los científicos se han basado en una descripción del dolor en la zona de la ATM, alteraciones en el área de la cavidad bucal y dolores de cabeza. Costen sugirió que los sujetos que presentan pérdida de soporte dental distal están predispuestos a un desplazamiento condilar dorsocraneal del tímpano, con compresión de la trompa de Eustaquio, del nervio auriculo-temporal y de la chorda timpánica [22] [23] [25] [26] [27].

En 1962 Pinto [22] describió un ligamento que conecta la ATM con el martillo a través del canal de Huguier en la fisura petrotimpánica. El autor afirma que los TTM se deben a una excesiva presión mecánica ejercida en el ligamento discomalleolar por tensión directa sobre el nervio auriculotemporal. Unos cambios de tensión de los músculos maxilares podrían someter a estimulación mecánica las estructuras en el interior de la fisura petrotimpanica. Esto podría conducir a cambios en la micro-circulación, como hipoxia o isquemia [22] [25] [26] [27].

Se ha estudiado la correlación entre las características anatómicas de la fisura petrotimpanica (PTF) y la aparición de *tinnitus*. La PTF se ha clasificado en tres tipos: tipo 1 (formación tubular ancha), tipo 2 (estructura cónica doble) y tipo 3 (estructura cónica simple). Se ha demostrado por primera vez una estrecha correlación entre ubicación, forma de entrada a la fisura petrotimpanica y el desplazamiento condilar hacia distal. Según Peroz [27] los síntomas otológicos con otoscopia negativa indican alteraciones en ATM y los TTM van acompañados de dolor de oído (37%) y *tinnitus*. En el desarrollo de acufenos juega un papel importante también la dislocación del disco. Cuanto más masivo sea el desplazamiento, mayor será la presencia de derrame intraarticular. Este también juega un papel importante en la generación de *tinnitus* [27].

La presencia de *tinnitus* en pacientes con TTM se ha explicado, según la teoría neuromuscular, debido a la existencia de estructuras comunes que unen la articulación temporo-mandibular y el aparato auditivo a través de ligamentos y sistema de inervación. Sin embargo, la teoría somatosensorial explica la correlación entre la severidad del *tinnitus* y el dolor crónico. Además, demuestra como dolor crónico y depresión puedan inducir cambios en el sistema nervioso central, con la consiguiente hipersensibilidad sensorial y la alteración de la percepción de los estímulos auditivos [(22)].

4.5 Alteración del comportamiento

El termino *tinnitus* ha sido descrito por muchos autores como un síntoma muy incapacitante y su severidad está asociada a depresión, irritabilidad, desorden del sueño, ansiedad y además se considera responsable de alteraciones del comportamiento y del deterioro de la calidad de la vida [(22) (28)]. Según Belli y cols. los pacientes que presentan *tinnitus* sufren ansiedad y depresión. Ellos afirmaron que la presencia de ansiedad, depresión y síntomas psiquiátricos deben alertar sobre la presencia de una condición psiquiátrica compleja [(9) (28)]. Kehrle y cols. compararon una muestra de sujetos que padecían acufenos con otra que no presentaba tinnitus. El nivel de depresión y ansiedad han sido evaluados utilizando la métrica más común a la hora de evaluar estas dos condiciones: el inventario de depresión de Beck y el inventario de ansiedad de Beck. En todos los pacientes se ha visto una estrecha relación entre tinnitus y ansiedad y depresión [(29)]. Se ha analizado un estudio en el que, sobre una muestra de 196 sujetos, entre los que presentaban pérdida auditiva el 8,7% sufrían de ansiedad. Mientras que entre los que presentaban acufenos, el 86% tenían ansiedad. Esto afirma una vez más que el acufeno se puede considerar la causa dominante de ansiedad [(28)]. En su revisión sistemática Geocze et al. [(9)] demostraron que sobre 18 estudios llevados a cabo entre el 1982 y el 2011, había correlación positiva entre acufenos y depresión. Pueden existir tres tipos de relaciones entre depresión y *tinnitus*: la depresión que predispone al *tinnitus*, *tinnitus* que predispone a la depresión y *tinnitus* que aparece como comorbilidad en pacientes con depresión. En la mayoría de los estudios resulta que la depresión predispone al *tinnitus* u ocurre como consecuencia de éste. Se ha observado, entre los sujetos que presentaban acufenos durante los últimos 12 meses, mayor presencia de depresión y ansiedad en comparación con los sujetos que no los presentaban. Además, los pacientes que consideraban el *tinnitus* como un problema muy grande tenían de cuatro a seis veces mas posibilidad de tener ansiedad y depresión en comparación con los pacientes que no sufrían *tinnitus* o los que no lo consideraban un gran problema. La literatura atribuye la relación de depresión y ansiedad con el *tinnitus* al carbonatado de estaño [(9)]. Entre las personas que presentan *tinnitus* crónico, el problema presente con mayor frecuencia es la alteración del sueño, que está relacionado con el nivel de severidad del *tinnitus.* Se ha estudiado una diminución de las horas de sueño por noche, que equivale a una pérdida de 80 minutos de sueño por semana, casi el equivalente a una noche entera de sueño perdido por mes. Los sujetos de edad avanzada que presentan *tinnitus* sufren mayor alteración del sueño respecto a los sujetos mas jóvenes. Los estudios demuestran también una importante relación entre los síntomas del *tinnitus* y la pérdida de días laborales, que lleva a una perdida del puesto de trabajo [(9) (29)].

Al contrario de la mayoría de las literaturas, Ooms y cols. [(28)] afirman que el *tinnitus* no presenta ninguna relación con la depresión. Mientras que, de acuerdo con la mayoría de los autores, existen estudios de neuroimagen que demuestran la activación de circuitos tanto en la depresión como en el *tinnitus*. Se han demostrado alteraciones del eje HHA (hipotálamico-hipofisario-adrenal) en depresión y en *tinnitus* a través de estudios de neurotransmisión, los cuales demuestran que el núcleo coclear dorsal, generalmente hiperactivo en *tinnitus*, está también implicado en el control de la atención y respuestas emocionales. Para que el paciente presente una correcta audición es imprescindible que el eje hipotalámico-hipofisario-adrenal (HHA) funcione normalmente. Estudios demuestran que la presencia de *tinnitus* está acompañada por signos de deterioro del eje HHA además de mayor presencia de estrés, comparado con pacientes que no presentan acufenos. El sistema límbico es el encargado de regular el estrés, y se ha visto que este sistema está activado en presencia de *tinnitus.* Esto representa, una vez más, la relación existente entre *tinnitus* y estrés [(28)].

Un estudio transversal realizado por G. Fernandes y cols. [(7)] informa sobre la asociación entre los TTM y el estado psicológico del paciente. Los que presentan un TTM desarrollan niveles más altos de depresión. La presencia de bruxismo nocturno se considera un factor influyente en el desarrollo de esta condición [(7)].

4.6 Propagación del sonido a través del hueso mandibular

La excitación del sonido a través de los dientes y del hueso mandibular se transmite a la cóclea por conducción ósea. Si se coloca el dedo índice en la oreja y se realizan movimientos de apertura y cierre de la boca, se percibe el desplazamiento del cóndilo de la mandíbula y el cambio de tamaño del canal auditivo externo [(30)].

En los estudios llevados a cabo por Tonndorf en 1966 [(31)] se han descrito tres mecanismos involucrados en la conducción ósea del sonido:

- El primer punto se basa en la transmisión del sonido a través de los huesos del cráneo y otras estructuras adyacentes (mandíbula y partes blandas) hasta el conducto auditivo externo (CAE).
- En el segundo se describe la estrecha unión entre los huesecillos del oído medio con el hueso temporal y la cápsula ótica.

- En el tercer punto las vibraciones de las estructuras craneales contribuyen a producir compresión y expansión de la cápsula ótica. Como consecuencia se aprecia un desplazamiento de los líquidos laberínticos y de la membrana basilar que provocan la estimulación de las células ciliadas [(31)].

La posibilidad de que la mandíbula pueda transmitir vibraciones al canal auditivo externo y producir presión sonora sobre esta fue descrita por primera vez por Von Békésy en 1960. Éste afirmó que el 50% de la energía sonora percibida como la propia voz se transmite a la cóclea por conducción ósea, mientras que el resto se transfiere por conducción aérea a través del oído externo y medio. Científicos han podido observar la importancia que tiene el ligamento situado entre el martillo y la articulación temporo-mandibular a la hora de transmitir las vibraciones sonoras [(32)]. Numerosos estudios han centrado su atención en entender como fuera posible que los dientes inferiores tuvieran una mejor conducción de sonido y produjesen mejores umbrales con respecto a los del maxilar superior, ya que la mandíbula no se encuentra conectada con el cráneo a través de tejido duro (hueso), sino que lo hace a través de la articulación temporo-mandibular (ATM) por liquido sinovial, ligamentos y otros tejidos blandos. Experimentos en animales han permitido estudiar las posibles vías de trasmisión de la frecuencia acústica desde los dientes inferiores hasta el oído medio. Probablemente la vibración de los dientes da lugar a una vibración del cuerpo de la mandíbula que a su vez induce la vibración del tejido blando circundante. Este último es muy improbable que pueda causar una vibración del hueso del cráneo. Se puede plantear que debido a que los tejidos blandos se comportan acústicamente como el agua, las vibraciones del sonido se trasmiten por canales de fluidos que rodean los vasos sanguíneos y los nervios alrededor de la mandíbula a través de sus agujeros en el cráneo donde establecen ondas de presión hidroacústica en el cerebro y líquido cefalorraquídeo (LCR). Éstos a su vez se comunican directamente con el oído interno utilizando canales de líquido.

Estas vías de propagación de sonido a través de los dientes están involucradas en la audición bajo del agua por ejemplo, en el caso de los delfines, que presentan una elevada sensibilidad auditiva en su mandíbula y tienen un tejido especial que permite la comunicación desde allí hasta la oreja. Otro ejemplo está representado por los ratones ciegos, que escuchan las vibraciones del suelo producidas por eventos sísmicos apoyando su mandíbula en el suelo. Gracias a estos ejemplos se puede relacionar la capacidad que los humanos tienen de escuchar utilizando la conducción ósea en sus dientes (12).

4.7 Sistema SoundBite

A diferencia de los audiófonos convencionales, que hacen que el sonido viaje hacia el oído por conducción aérea, la tecnología SoundBite consiste en un dispositivo intraoral de conducción ósea. Se trata de un sistema auditivo no quirúrgico diseñado para trasmitir el sonido a través de dientes y hueso. Está constituido por un micrófono retro auricular (del inglés BTE) que alberga al receptor, un transmisor inalámbrico con micrófono y un dispositivo extraíble intraoral (del inglés ITM) (Figura 12). El micrófono se coloca en el canal auditivo y, una vez capturado el sonido, es procesado por el BTE (Figura 13) y luego trasmitido de manera inalámbrica al dispositivo ITM (Figura 14). Este produce unas vibraciones que se conducen a través de dientes y huesos para ambas cócleas (14)(30).

Figura 12

En la imagen se pueden apreciar los componentes del sistema SoundBite en la boca (a la derecha) y en la oreja (a la izquierda) [14].

El componente ITM no cubre las superficies oclusales de los dientes y, además, ya que el micrófono no se coloca en la boca, no existe una amplificación de los sonidos de la masticación. La ingestión de líquidos y de alimentos puede ocurrir mientras se use el dispositivo [14]. Este sistema proporciona un sonido claro y restaura la audición a pacientes con sordera parcial, causada por tumores benignos, infecciones o traumatismos, que buscan un tratamiento no quirúrgico. Para entender como el odontólogo participa en la elaboración de este dispositivo, hay que considerar que SoundBite es un dispositivo parecido a una prótesis parcial removible o un retenedor, colocado en el arco maxilar. Es muy pequeño y no influye en el habla de hecho, los pacientes lo consideran muy cómodo, sobre todo los que han tenido experiencias previas de aparatos removibles en la boca. Se puede colocar en cualquiera de los dos lados. Es fundamental, antes de colocarlo, realizar al paciente un examen completo, incluidas las radiografías y el sondaje. Tiene que estar sano a nivel dental y periodontal, no debe de presentar caries activas, bolsas periodontales ni infecciones, sobre todo en los dientes pilares. Se ha visto su éxito en dientes que presentaban endodoncias, coronas, empastes o implantes. En cambio, tener un diente desgastado, una corona mal ajustada, alteraciones anatómicas o mal posicionamiento de los dientes en la arcada influye en la retención del dispositivo. Podría ser necesario un tratamiento de ortodoncia previo a la colocación de SoundBite para llevar los dientes a su sitio y tener máxima eficacia del dispositivo. Este aparato suele estar en contacto con dientes, encía y mejilla; en la parte bucal, entre los dientes más distales, está encajada la parte que crea el sonido mientras que por lingual están los componentes electrónicos que a través de un cable que atraviesa la superficie distal de los dientes posteriores conecta la parte bucal a la lingual[30].

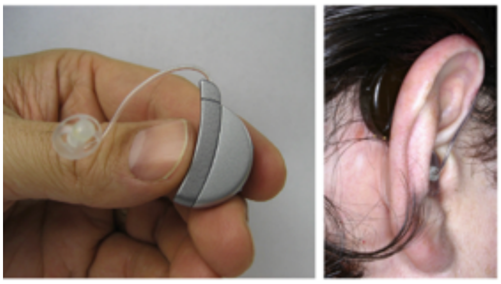

Figura 13

Imagen de la unidad de micrófono BTE que aloja el receptor, el transmisor inalámbrico y el micrófono adjunto [30].

Para su fabricación el odontólogo tiene que empezar tomando una impresión de ambos maxilares en alginato y vaciarla para obtener posteriormente un modelo de escayola. En este caso es fundamental que en la toma de impresión salga perfectamente el diente más distal.

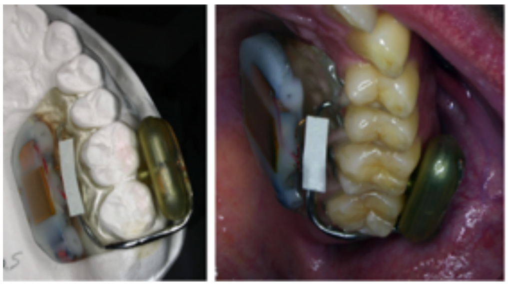

Figura 14

Representación del dispositivo ITM capaz de recibir información de manera inalámbrica desde el transmisor y producir vibraciones imperceptibles que viajan a través de dientes y hueso hasta la cóclea [30].

Como todos los aparatos dentales removibles, este también puede presentar efectos secundarios. Hay que informar al paciente sobre la posibilidad de tener inflamación gingival o sensación de dolor. Fundamental la limpieza del dispositivo, que tiene que realizarse con cepillo de dientes y pasta o en alternativa se puede utilizar el jabón de manos. En el momento de la entrega del dispositivo, hay que dejar que el paciente lo coloque y lo retire del modelo de escayola antes de colocarlo en su boca. Es posible aumentar la retención apretando el dispositivo entre pulgar y dedo índice o realizar algunos ajustes utilizando un alicate de 3 puntas, teniendo cuidado para no dañar los cables. Independientemente de los ajustes que se vayan a realizar es muy importante tener contralada la oclusión del paciente, utilizando papel de articular; en ningún caso el dispositivo tiene que influir en esta o modificarla [30].

8. CONCLUSIONES

1. Los estudios analizados han llevado a concluir que la existencia de estructuras comunes entre articulación temporo-mandibular (ATM) y el oído hace que exista una relación entre los trastornos temporo-mandibulares (TTM) y los problemas otológicos. Varias son las alteraciones que ambas estructuras pueden causar a la otra. Entre todas la más común es el *tinnitus*.
2. Se ha llegado a demostrar la capacidad que el hueso mandibular y los elementos dentarios tienen de propagar las vibraciones sonoras a través del hueso y se ha visto que la conducción ósea es más efectiva para la transmisión de información sonora con respeto a la conducción aérea. Los primeros aparatos capaces de conducir las vibraciones sonoras a través del hueso eran implantes osteointegrados. A partir de allí han ido evolucionando hasta llegar a la realización, hoy en día, de un sistema que permite la conducción ósea del sonido sin la necesidad de estar implantado en el hueso. Se trata de un aparato llamado SoundBite que no requiere colocación quirúrgica; permite al paciente de ponerlo y quitarlo libremente, ofreciendo la calidad de percepción sonora equivalente a los implantes osteointegrados.
3. La mandíbula en el curso de la evolución ha ido cambiando hasta llegar a la formación de unos huesecillos que componen el oído medio. Por lo tanto, se puede afirmar que estas dos estructuras anatómicas están fuertemente relacionadas entre ellas. El enlace tan fuerte entre la cavidad oral, en específico el hueso mandibular, y las estructuras auriculares está demostrada gracias a la presencia de TTM que llevan al avance de alteraciones a nivel otológico.

4. Numerosos estudios demuestran la existencia de alteraciones en el comportamiento de individuos afectados por *tinnitus* y trastornos temporo-mandibulares. Se puede concluir que en los sujetos estudiados existe una estrecha relación del *tinnitus* con ansiedad, depresión y estrés. Además, se ha visto como el *tinnitus* crónico influye en el normal desarrollo de las horas de sueño. Todo esto afecta negativamente en la calidad de vida de los individuos. Los pacientes que padecen TTM también se han visto afectados por elevados niveles de depresión.

La descripción del dispositivo SoundBite, que representa una alternativa a los audífonos osteointegrados, permitiendo a los pacientes de beneficiar de un aparato de transmisión ósea del sonido sin someterse a una cirugía, hace que el presente trabajo incluya los conceptos de sostenibilidad medioambiental y social puesto que contribuye en mejorar la calidad de vida de las personas que lo llevan.

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10. ANEXOS

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REVIEW

Evolution of the mammalian middle ear: a historical review

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Abstract

Here we present a brief, historical review of research into the mammalian middle ear structures. Most of their essential homologies were established by embryologists, notably including Reichert, during the 19th century. The evolutionary dimension was confirmed by finds of fossil synapsids, mainly from the Karroo of South Africa. In 1913, Ernst Gaupp was the first to present a synthesis of the available embryological and paleontological data, but a number of morphological details remained to be solved, such as the origin of the tympanic membrane. Gaupp favoured an independent origin of the eardrum in anurans, sauropsids, and mammals; we support most of his ideas. The present review emphasizes the problem of how the mammalian middle ear structures that developed at the angle of the lower jaw were transferred to the basicranium; the ontogenesis of extant marsupials provides important information on this question.

Key words: evolution; Mammalia; middle ear; middle ear ossicles; ontogeny.

Introduction

The study of the mammalian middle ear has been one of the central themes of vertebrate morphological research of the last 200 years. The middle ear ossicles have, of course, been known to human anatomists for much longer, as shown by their visual representation in Vesalius (1543). The middle ear ossicles of amphibians, sauropsids (reptiles and birds), and mammals were described in detail by Cuvier (1800) but the observed differences were not considered at that time.

An improved theoretical understanding – beyond mere description – of the delicate middle ear structures only became possible through the comparative embryological approach developed during the first decades of the 19th century, as excellently reviewed by Russell (1916).

Early embryological studies

During the four decades after Cuvier, embryological studies of all classes of vertebrates clarified the homologies of the middle ear structures, which, prior to Owen (1843), were more usually referred to as analogies. Carus (1818) had doubted that the articulation of the lower jaw is identical between mammals and the other vertebrates, and he recognized that the incus (anvil) is homologous to the quadrate of 'lower' (i.e. non-mammalian) vertebrates. Meckel (1820) observed that, in mammals, the embryonic malleus (hammer) develops from the posterior end of a thin rod of cartilage attached to the medial side of the dentary, whereas in non-mammalian vertebrates this posterior end ossifies as the articular bone; Meckel therefore homologized the malleus with the articular. The embryonic cartilage of the lower jaw is now called 'Meckel's cartilage' after its discoverer. These discoveries replaced some earlier homologizations, such as those of Geoffroy-Saint-Hilaire (1818).

These finds gained a new importance when Rathke (1825a,b) described *Kiemenspalten* (gill slits) and *Kiemenbögen* (gill arches) in embryos of the pig and chick. The discovery of *Kiemen-Anlagen* (gill anlagen) stimulated a number of similar studies on many different amniotes, including man. These early studies suggested that the most anterior of the *Kiemenbögen* represents the mandibular arch and that the second represents the hyal arch (Baer, 1828). The term *Kiemenbogen* was accordingly replaced by the more general terms *Visceralbogen* (visceral arch) or *Schlundbogen* (pharyngeal arch). Huschke (1827, 1828)

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DEVELOPMENTAL DYNAMICS 240:2466–2473, 2011

RESEARCH ARTICLE

Tissue Interaction Is Required for Glenoid Fossa Development During Temporomandibular Joint Formation

Ying Wang,[1,2†] Chao Liu,[2†] Joseph Rohr,[2] Hongbing Liu,[2] Fenglei He,[2‡] Jian Yu,[2] Cheng Sun,[2] Lu Li,[2] Shuping Gu,[2] and YiPing Chen[2*]

The mammalian temporomandibular joint (TMJ) develops from two distinct mesenchymal condensations that grow toward each other and ossify through different mechanisms, with the glenoid fossa undergoing intramembranous ossification while the condyle being endochondral in origin. In this study, we used various genetically modified mouse models to investigate tissue interaction between the condyle and glenoid fossa during TMJ formation in mice. We report that either absence or dislocation of the condyle results in an arrested glenoid fossa development. In both cases, glenoid fossa development was initiated, but failed to sustain, and became regressed subsequently. However, condyle development appears to be independent upon the presence of the forming glenoid fossa. In addition, we show that substitution of condyle by Meckel's cartilage is able to sustain glenoid fossa development. These observations suggest that proper signals from the developing condyle or Meckel's cartilage are required to sustain the glenoid fossa development. *Developmental Dynamics 240:2466–2473, 2011.* © 2011 Wiley Periodicals, Inc.

Key words: TMJ formation; glenoid fossa development; condyle; tissue interaction; Sox9

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INTRODUCTION

The temporomandibular joint (TMJ) is a unique synovial joint that is essential for movement and function of the jaw in mammals. It is composed of a fibrous capsule that encloses the mandibular condyle, the glenoid fossa of the temporal bone, and an articulating disc separating the two articular facets lined with fibrocartilage instead of hyaline cartilage (Sperber, 2001). The glenoid fossa forms a deep concavity in the temporal bone, receiving the mandibular condyle to make the hinge of TMJ function. Associated with the TMJ are also the tendon of the pterygoid muscle and various surrounding ligaments. The TMJ disorders affect a large population in human beings, causing chronic myofacial pains and difficulty in chewing function. While the structures and functions of the TMJ have been well documented, TMJ development remains poorly understood in terms of underlying cellular and molecular mechanisms in contrast to a wealth of information regarding the formation of synovial joints in the developing limb.

The TMJ develops from two distinct and separate mesenchymal condensations, the temporal and condylar blastemas. These two blastemas grow toward each other and undergo different ossification processes, forming the glenoid fossa and condyle, respectively. Despite that it is classified as synovial

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CRANIOFACIAL SKELETON (WE ROBERTS, SECTION EDITOR)

Part I: Development and Physiology of the Temporomandibular Joint

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Abstract

Purpose of Review Investigate the developmental physiology of the temporomandibular joint (TMJ), a unique articulation between the cranium and the mandible.

Recent Findings Principal regulatory factors for TMJ and disc development are Indian hedgehog (IHH) and bone morphogenetic protein (BMP-2). The mechanism is closely associated with ear morphogenesis. Secondary condylar cartilage emerges as a subperiosteal blastema on the medial surface of the posterior mandible. The condylar articular surface is immunoreactive for tenascin-C, so it is a modified fibrous periosteum with an underlying proliferative zone (cambrium layer) that differentiates into fibrocartilage. The latter cushions high loads and subsequently produces endochondral bone. The TMJ is a heavily loaded joint with three cushioning layers of fibrocartilage in the disc, as well as in subarticular zones in the fossa and mandibular condyle.

Summary The periosteal articular surface produces fibrocartilage to resist heavy loads, and has unique healing and adaptive properties for maintaining life support functions under adverse environmental conditions.

Keywords TMJ · Indian hedgehog · BMP-2 · Healing blastema · Tenascin-C · Fibrocartilage · Periosteum · Morphogenesis · Pharyngeal arch

Introduction

The temporomandibular joint (TMJ) is a synovial joint comprised of the mandibular condyle and glenoid fossa of the temporal bone. An intermediate articular disc of fibrocartilage divides the joint cavity into upper and lower compartments. The surrounding connective tissue capsule is attached to muscles and tendons (Fig. 1).

This article is part of the Topical Collection on *Craniofacial Skeleton*

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The capsule is lined by a synovium that secretes lubricating synovial fluid. The articular disc is attached to the capsule and positioned between the mandibular condyle and the glenoid fossa. The TMJs are very mobile bilateral articulations of the mandible, a bone that is highly evolved for accommodating a variety of respiratory, speech, and omnivore masticatory functions. It can be argued that the mandible has a stronger influence on the human gene pool than any other bone in the body because it is essential for three important elements of survival and propagation: mastication, communication, and routine mating success. Anomalies and trauma to the mandible and TMJ may interfere with life support functions. They often manifest as a facial esthetic deficit with craniomandibular disorder (CMD) symptoms including ear pain and tinnitus [2].

The evolutionary origin of the mammalian TMJ is intimately connected with that of the middle ear bones [3]. Mammals have three middle ear bones, the malleus, incus, and stapes. Reptiles and birds have only one middle ear bone that is homologous to the mammalian stapes. Based on anatomical comparisons, Reichert (1837) [4] proposed that the additional two mammalian middle ear bones were homologous to the quadrate of the non-mammalian jaw joint and Gaupp (1912) [5] extended this idea by describing the development of a primary jaw joint between the malleus and the incus, and a secondary jaw joint, unique to mammals, between

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Trastornos temporomandibulares y dolor orofacial crónico: al final, ¿a qué área pertenecen?

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Willeman Bastos Tesch LV, de Souza Tesch R, Pereira Jr. FJ. Trastornos temporomandibulares y dolor orofacial crónico: al final, ¿a qué área pertenecen? Rev Soc Esp Dolor 2014; 21(2): 70-74.

ABSTRACT

Temporomandibular disorders (TMD) can be defined as a set of painful and/or dysfunctional conditions, involving the masticatory muscles and/or the temporomandibular joint (TMJ). They commonly affect women during the reproductive years and its prevalence drastically decreases as result from ageing. Due to the complex multifactorial nature of TMD, it is essential the broad interdisciplinary research, basic and clinical, that supports developing evidence-based strategies being able to prevent, diagnose and manage these chronic conditions in a more effective and safe way.

Key words: Chronic pain. Temporomandibular disorders.

RESUMEN

Los trastornos temporomandibulares (TTM) se pueden definir como un conjunto de condiciones dolorosas y/o disfuncionales en los músculos masticatorios y/o en la articulación temporomandibular (ATM). Comúnmente afectan a las mujeres durante los años reproductivos y su prevalencia disminuye bruscamente con la edad. Debido a la compleja naturaleza multifactorial de los TTM, es fundamental la investigación interdisciplinar amplia, básica y clínica que permita el desarrollo de estrategias basadas en evidencias capaces de prevenir, diagnosticar y tratar estos trastornos crónicos de manera más eficaz y segura.

Palabras clave: Dolor crónico. Trastornos temporomandibulares.

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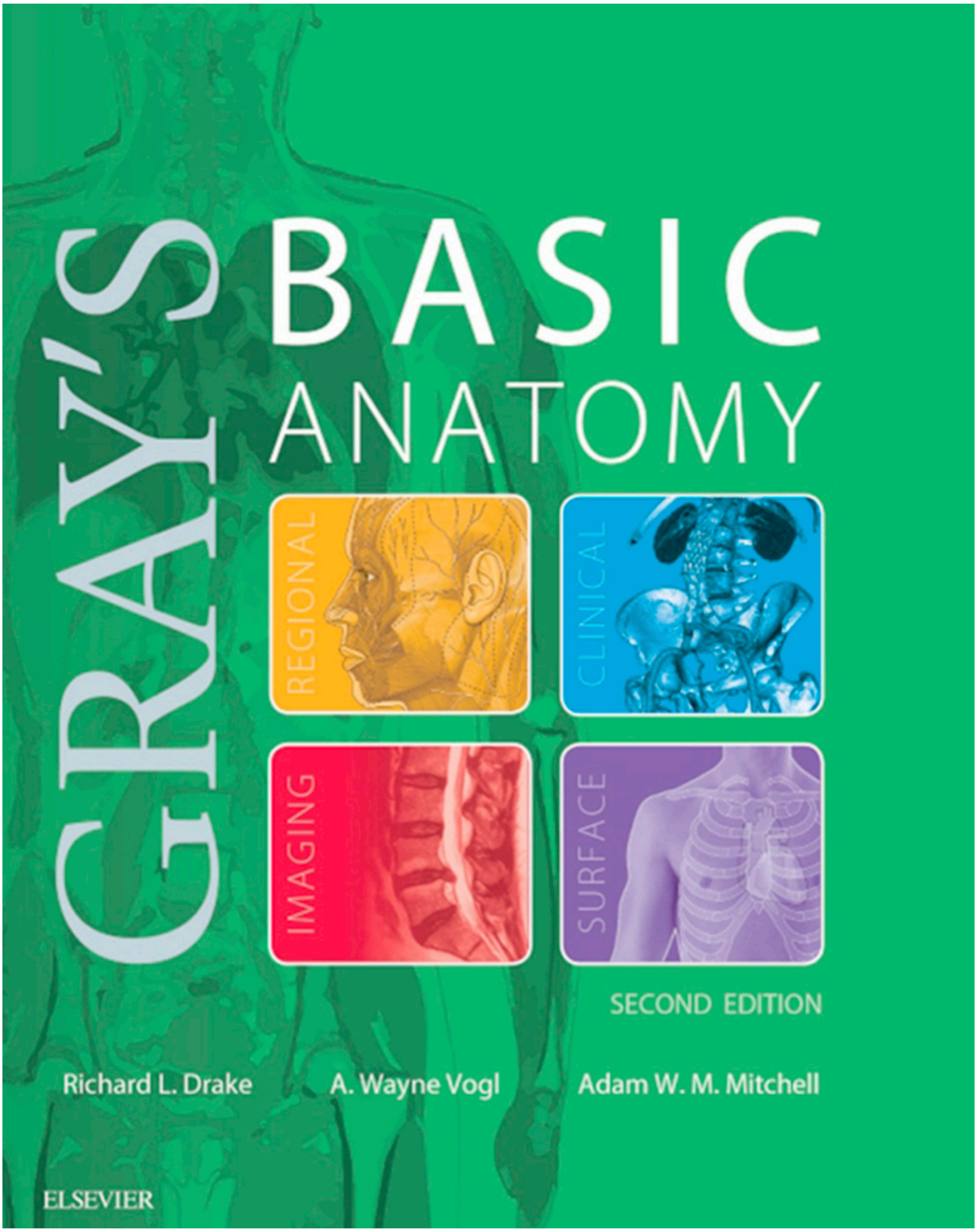
INTRODUCCIÓN

Los trastornos temporomandibulares (TTM) se pueden definir como un conjunto de condiciones dolorosas y/o disfuncionales en los músculos masticatorios y/o en la articulación temporomandibular (ATM). Comúnmente afectan a las mujeres durante los años reproductivos y su prevalencia disminuye bruscamente con la edad (1). Además de la predisposición innata relacionada con el sexo y la edad, la exposición a muchos otros factores fue investigada en relación con un mayor riesgo de desarrollar TTM. La parafunción oral de apretamiento dental durante el día y el bruxismo del sueño están estrechamente asociados con la presencia de TTM.

Probablemente esta diversidad de factores de riesgo hace que la aparición de estos trastornos sea tan común, ya que ocupa el tercer lugar en prevalencia entre los dolores crónicos, solamente después de los dolores de cabeza primarios y del dolor de espalda, de acuerdo con las evidencias disponibles. El TTM es la más común de todas las condiciones dolorosas crónicas que afectan a la región orofacial.

Inevitablemente, todos estos procesos están asociados con funciones psicológicas y psicosociales de gran importancia que fundamentan el desarrollo de características únicas, intrapersonales y psicosociales que distinguen a un individuo de otro. La justificación de la inclusión de los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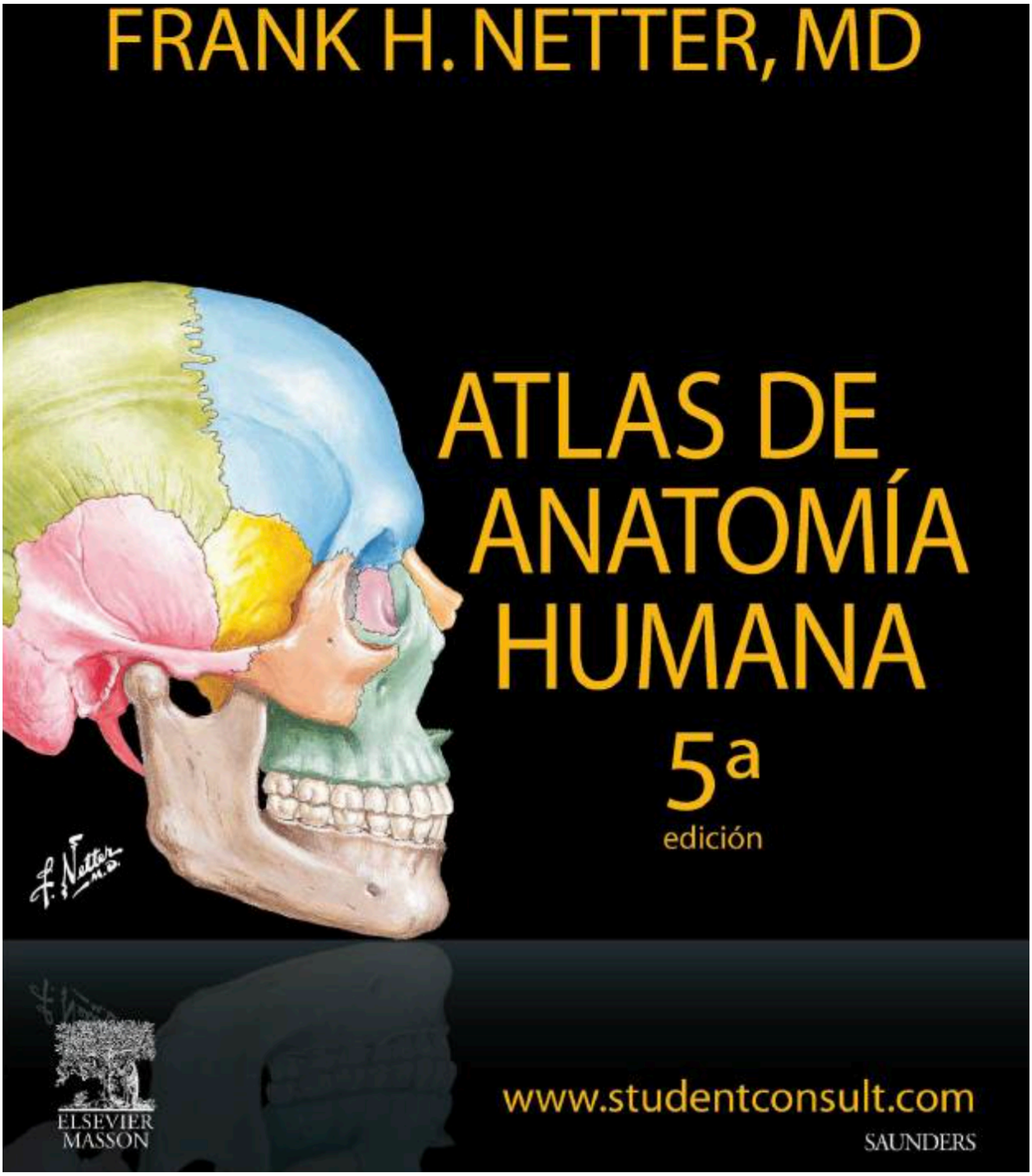
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Sleep bruxism increases the risk for painful temporomandibular disorder, depression and non-specific physical symptoms

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SUMMARY To explore the relationship between sleep bruxism (SB), painful temporomandibular disorders (TMD) and psychologic status in a cross-sectional study. The sample consisted of 272 individuals. The Research Diagnostic Criteria for TMD (RDC/TMD) was used to diagnose TMD; SB was diagnosed by clinical criteria proposed by The American Academy of Sleep Medicine. The sample was divided into four groups: (1) patients without painful TMD and without SB, (2) patients without painful TMD and with SB, (3) patients with painful TMD and without SB and (4) patients with painful TMD and with SB. Data were analysed by Odds Ratio test with a 95% confidence interval. Patients with SB had an increased risk for the occurrence of myofascial pain (OR = 5·93, 95% CI: 3·19–11·02) and arthralgia (2·34, 1·58–3·46). Group 3 had an increased risk for moderate/severe depression and non-specific physical symptoms (10·1, 3·67–27·79; 14·7, 5·39–39·92, respectively), and this risk increased in the presence of SB (25·0, 9·65–64·77; 35·8, 13·94–91·90, respectively). SB seems to be a risk factor for painful TMD, and this in turn is a risk factor for the occurrence of higher depression and non-specific physical symptoms levels, but a cause–effect relationship could not be established.

KEYWORDS: arthralgia, depression, facial pain, risk groups, sleep bruxism

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Introduction

The International Association for the Study of Pain (IASP) defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in these terms (1). It is understood that pain is a complex phenomenon influenced by biological and psychological factors.

The most frequent presenting symptom associated with temporomandibular disorder (TMD) is pain, usually localised in the masticatory muscles and/or the temporomandibular joints (TMJs). TMD is a collective term that embraces a number of clinical problems, which involve the masticatory muscles, the TMJs and the associated structures (2). The aetiology of TMD has been considered multifactorial, because one or more factors may contribute to its predisposition, initiation and maintenance. Among these factors, sleep bruxism and psychological factors may be mentioned, which can be considered factors involved in the initiation and/or maintenance of TMD (3).

The American Academy of Sleep Medicine (AASM) classified SB as a stereotyped movement disorder occurring during sleep and characterised by tooth grinding and/or clenching (4). Although previous studies have explored the association of bruxism with symptoms of TMD, the findings were not conclusive. In general, studies have verified a strong association between SB and the presence of TMD signs and symptoms, as well as increased risk for their development (5–9).

Another conditions closely linked to the aetiology of TMD are related to psychological conditions. Many

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Mandible Protrusion and Decrease of TMJ Sounds: An Electrovibratographic Examination

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This study quantified by, electrovibratography, the amount of mandible protrusion required to decrease significantly temporomandibular joint (TMJ) vibratory energy as an aid in the diagnosis of the recapture of anteriorly displaced disk. Eighteen patients diagnosed as having anterior disk displacement with reduction and TMJ clicking were submitted to electrovibratographic examination at the first appointment and treated with a stabilizing appliance and anterior positioning appliance with 1 to 5 mm protrusion. Vibratory energy was checked in each of these positions. Baseline data were used as control. At the first appointment, the patients had vibrations with more elevated intensities at the middle and late phases of the mouth opening cycle. At only one clinical step, mandible protrusion was obtained with the anterior repositioning appliance, ranging from 1 to 5 mm protusion. At each new position, a new electrovibratographic exam was made. After the 5-mm mandibular projection, only 2 patients presented vibration, with means between 0.6 and 2.8 Hz. Data were analyzed statistically by ANOVA and Tukey's test (α=0.05). The outcomes of this study indicate that 3 mm is the minimum amount of mandible protrusion to significantly decrease the TMJ vibratory energy and to recapture the displaced articular disk.

Key Words: temporomandibular joint, temporomandibular joint disorders, electrovibratography, dental occlusion.

INTRODUCTION

Anterior disk displacement with reduction is an internal temporomandibular joint (TMJ) disorder in which one of the most important characteristics is reciprocal clicking. Occlusal derangements, deep bite with insufficient horizontal overlap (1), interceptive occlusal contacts in the anterior teeth (2) and inadequate muscular activity of lateral pterygoid muscle (3) seem to be important in the development of this condition. Reflex activities are released, projecting the jaw backwards, producing morphologic alteration in the posterior border of the disk and elongating the ligaments that connect the disk to the condyle (4).

These alterations make the disk unstable on the condyle and, hence, it can move forwards. During mouth opening, the condyle moves forwards and passes over the posterior border of the disk until reaching its central portion. In the late phase of mouth closing, the disk is displaced again, producing a low-intensity sound attributed to condyle sliding on the retrodiscal area (5).

Clicking and crepitation should be considered as signs of morphological alterations, being indicative of anterior disk displacement with reduction (5) and arthrosis, respectively. Electrovibratographic records and macroscopic examinations of articulations of corpses showed that 20% of the TMJs with clicking had the disk displaced anteriorly and 22% of the TMJs with crepitation had arthrosis or disk perforation (6). Later recapture of the disk causes clicking at the end of mouth opening and indicates that the bilaminar zone is more affected (7). The microscopic aspects of disk surface can also be altered (8).

Several methods have been used to treat anterior

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The Laryngoscope

Relationships Between Tinnitus and the Prevalence of Anxiety and Depression

Jay M. Bhatt, MD; Neil Bhattacharyya, MD, FACS; Harrison W. Lin, MD

Objectives/Hypothesis: Quantify the relationships between tinnitus, and anxiety and depression among adults.

Study Design: Cross-sectional analysis of a national health survey.

Methods: Adult respondents in the 2007 Integrated Health Interview Series tinnitus module were analyzed. Data for tinnitus symptoms and severity and reported anxiety and depression symptoms were extracted. Associations between tinnitus problems and anxiety, depression, lost workdays, days of alcohol consumption, and mean hours of sleep were assessed.

Results: Among 21.4 ± 0.69 million adult tinnitus sufferers, 26.1% reported problems with anxiety in the preceding 12 months, whereas only 9.2% of those without tinnitus reported an anxiety problem ($P < .001$). Similarly, 25.6% of respondents with tinnitus reported problems with depression, whereas only 9.1% of those without tinnitus reported depression symptoms ($P < .001$). Those reporting tinnitus symptoms as a "big" or "very big" problem were more likely to concurrently report anxiety (odds ratio [OR]: 5.7; 95% CI: 4.0-8.1; $P < .001$) and depression (OR: 4.8; 95% CI: 3.5-6.7; $P < .001$) symptoms. Tinnitus sufferers reported significantly fewer mean hours of sleep per night (7.00 vs. 7.21; $P < .001$) and greater mean days of work missed (6.94 vs. 3.79, $P < .001$) compared to those who did not report tinnitus. Mean days of alcohol consumption between the two groups were not significantly different.

Conclusions: Tinnitus symptoms are closely associated with anxiety, depression, shorter sleep duration, and greater workdays missed. These comorbidities and sequelae should be recognized and addressed to optimally manage patients with chronic and bothersome tinnitus.

Key Words: Tinnitus, depression, anxiety, sleep, work, productivity, substance abuse.

Level of Evidence: 4

***Laryngoscope*, 00:000–000, 2016**

INTRODUCTION

Tinnitus is the perception of sound in the absence of an external auditory stimulus, affecting 8% to 25.3% of the population of the United States and the world.[1–7] Psychiatric disorders such as anxiety and depression are often comorbid in patients with chronic tinnitus,[8–10] and these conditions can not only be troublesome and debilitating, they have been shown to increase morbidity and the risk of suicide among patients with tinnitus.[11]

Previous work has shed considerable light on the relationships between tinnitus symptoms and mood disorders. Sullivan and colleagues reported a 78% lifetime and 60% current prevalence of major depression among patients with tinnitus, which were rates substantially higher than the nontinnitus control subjects (21% and 7%, respectively).[12] Similarly, Belli and associates found that patients with chronic tinnitus had significantly higher Beck Anxiety Inventory and Beck Depression Inventory scores.[13] Notably, anxiety and depression severity have been correlated with tinnitus severity,[14] and tinnitus prevalence may even decrease within a cohort as depression symptoms improve.[15] Tinnitus is furthermore associated with sleep disorders, including insomnia, and can cause difficulty in initiating and maintaining sleep, and lead to poor overall quality of sleep.[16] These patients often suffer from greater distress and difficulty with concentration, irritability, and loss of control.[17]

In contrast, Shargorodsky et al., in their study of the National Health and Nutrition Examination Survey data, failed to find a significant association between frequent tinnitus and major depression.[6] Accordingly, we aimed to better evaluate the relationship of tinnitus symptoms with rates of mood disorders among adults by utilizing the tinnitus module from the 2007 National Health Interview Series. Additionally, we sought to further expand on the comorbidities associated with tinnitus by looking specifically at the relationship to sleep, work days missed, and alcohol abuse.

MATERIALS AND METHODS

Adult responses in the household-based 2007 National Health Interview Series (NHIS) were analyzed as aggregated in

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Review Article

Anxiety and depression, personality traits relevant to tinnitus: A scoping review

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The British Society of Audiology

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Abstract

Objective: Scoping reviews of existing literature were conducted to identify key personality traits relevant to tinnitus, and examine the relationship between affective disorders and tinnitus. *Design*: The methodological framework of Arksey and O'Malley was followed. *Study sample*: Sixty studies were chosen for charting the data, 14 studies examined personality traits exclusively, 31 studies examined affective disorders exclusively, and 15 studies investigated both. *Results*: The presence of one or more specific personality traits of high neuroticism, low extraversion, high stress reaction, higher alienation, lower social closeness, lower well-being, lower self control, lower psychological acceptance, presence of a type D personality, and externalized locus of control were associated with tinnitus distress. Anxiety and depression were more prevalent among the tinnitus clinical population and at elevated levels. *Conclusions*: Personality traits have a consistent association with the distress experienced by adult tinnitus help-seekers, and help-seekers are also more likely to experience affective symptoms and/or disorders.

Key Words: Tinnitus; psychosocial/emotional; hearing-related symptoms

Tinnitus in adults and personality: A scoping review of existing literature

Tinnitus is the perception of sound by an individual in the absence of an external sound (Andersson et al, 2005b; Tyler et al, 2006; Baguley, 2002; Kaltenbach, 2011). While 4–32% of the general population is thought to have constant tinnitus, it is only a subgroup of 15–20% of the tinnitus population who are distressed by it (Bauer & Brozoski, 2008; Lockwood et al, 2002; Hoffmann & Reed, 2004; Heller, 2003). Distressing or severe tinnitus is commonly characterized by one or more symptoms of disturbed sleep and concentration, problems with hearing, disruption to everyday activities, irritation and annoyance, anxiety and depression (Malouff et al, 2011). It is not fully understood why some individuals adapt to their tinnitus and why others do not (Scott & Lindberg, 2000). All of the distress caused by tinnitus is not explainable by its psychoacoustic characteristics (Scott et al, 1990). A large body of literature now suggests that psychological variables play an important role in tinnitus perception and distress (Malouff et al, 2011; Scott et al, 1990; Tyler et al, 2006; Searchfield et al, 2012; Andersson & Westin, 2008). Certain personality traits and psychological disorders, especially depression and anxiety, often coexist with tinnitus and may act as predictors for tinnitus severity (Belli et al, 2012; Langguth et al, 2011).

The term '*personality*' defines an individual's typical thoughts, actions, behaviours, and interaction style (Bouchard & Loehlin, 2001; Tellegen, 1982). The trait theory developed by Allport (1937) states that personality is composed of a set of broad dispositions or *traits*. Each trait is a dimension which lies in degrees along a continuum, and can be measured using self-report questionnaires (Eysenck, 1990; Costa & McRae, 1992; Allport, 1937; Patrick et al, 2002). Two popular personality trait models are Eysenck's three dimensional model (Eysenck, 1990) and the five factor model (FFM) (Costa & McRae, 1992). Neuroticism and extraversion traits are common to both models, and describe the tendency of an individual to experience negative emotions and the tendency to exhibit sociability, assertiveness and express emotion respectively. In the tinnitus population, high neuroticism and low extraversion has been often been reported (Rizzardo et al, 1998; McCormack et al, 2014; Bartels et al, 2010a). High stress reaction and low social closeness has been associated with tinnitus (Welch & Dawes, 2008). Bartels et al (2010a,b) also concluded that the presence of a specific type D personality (defined by a cluster of personality traits

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Acoustic and Physiologic Aspects of Bone Conduction Hearing

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Abstract

Bone conduction (BC) is the way sound energy is transmitted by the skull bones to the cochlea causing a sound perception. Even if the BC sound transmission involves several pathways including sound pressure induced in the ear canal, inertial forces acting on the middle ear ossicles and cochlear fluids, alteration of the cochlear space, and pressure transmission through the 3rd window of the cochlea, the BC sound ultimately produces a wave motion on the basilar membrane similar to that of air-conducted sound. The efficiency of the BC stimulation is largely dependent on the skull bone where the skull acts as a rigid body at low frequencies and incorporates different types of wave transmission at higher frequencies. The interaural stimulation difference is determined by the difference between contralateral and ipsilateral BC sound transmission: the transcranial BC sound transmission. To benefit from binaural processing, the transcranial transmission should be low, while the same should be high when using BC hearing aids for unilateral deaf subjects. By appropriately positioning the stimulation, high or low transcranial transmission can be achieved.

The conventional way of auditory stimulation is by an airborne sound that is transmitted through the ear canal, where it induces mechanical vibrations in the eardrum that are transmitted via the middle ear ossicles and become a sound pressure in the cochlea (scala vestibuli). This sound pressure acts on the basilar membrane producing a traveling wave that excites the sensory cells in the organ of Corti causing an auditory sensation. Bone conduction hearing is when the sound is transmitted through the skull bone, cartilage, skin and soft tissue, and fluids in the body, ultimately resulting in a sound pressure in the cochlear scalae. This type of sound transmission is sometimes divided between body conduction and bone conduction, where the latter is only sounds transmitted in the skull bone. Here, for simplicity, both body and bone conduction will be referred to as bone conduction and abbreviated BC.

Clinical Measurements using Bone Conduction

Understanding the processes of BC sound was early driven by its use for differential diagnosis between conductive and sensorineural hearing loss. In the 19th century, the usage of the tuning fork provided tests as Weber test and Rinne test [1]. After the introduction of the audiometer and

BONE CONDUCTION HEARING ON THE TEETH OF THE LOWER JAW

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ABSTRACT

Bone conduction stimulation of the teeth of the lower jaw initiates auditory sensations. However the lower jaw is only loosely coupled to the skull by the temporo-mandibular joint. Therefore the 'classical' bone conduction pathway involving skull vibration transmission entirely along bone to the temporal-petrous bone requires further consideration. Bone conduction hearing thresholds to stimulation at the forehead and at the teeth of the upper and lower jaw were determined in human subjects. Thresholds on the teeth were better than those on the forehead and there was no difference between the thresholds measured following stimulation of the upper and lower teeth. Experiments in guinea-pigs provided evidence that vibration of the teeth leads to transmission of the audio-frequency vibrations by means of soft tissue, through skull foramina, into the skull cavity (brain and CSF) and from there by fluid channels directly into inner ear fluids, exciting the cochlea.

KEY WORDS

bone conduction, teeth, temporo-mandibular joint, soft tissue, fluid channels

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OTOLOGY

Stability, survival, and tolerability of a 4.5-mm-wide bone-anchored hearing implant: 6-month data from a randomized controlled clinical trial

Rik C. Nelissen · Christine A. den Besten · Emmanuel A. M. Mylanus · Myrthe K. S. Hol

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Abstract The objective of this study was to compare the stability, survival, and tolerability of 2 percutaneous osseointegrated titanium implants for bone conduction hearing: a 4.5-mm diameter implant (test) and a 3.75-mm diameter implant (control). Fifty-seven adult patients were included in this randomized controlled clinical trial. Sixty implants were allocated in a 2:1 (test–control) ratio. Follow-up visits were scheduled at 7, 14, 21, and 28 days; 6 and 12 weeks; and 6 months. At every visit, implant stability quotient (ISQ) values were recorded by means of resonance frequency analysis (RFA) and skin reactions were evaluated according to the Holgers classification. Implants were loaded with the bone conduction device at 3 weeks. Hearing-related quality of life was evaluated using the Abbreviated Profile of Hearing Aid Benefit (APHAB), the Glasgow Benefit Inventory (GBI), and the Glasgow Health Status Inventory (GHSI). ISQ values were statistically significantly higher for the test implant compared to the control implant. No implants were lost and soft tissue reactions were comparable for both implants. Positive results were reported in the hearing-related quality of life questionnaires. These 6-month results indicate that both implants and their corresponding hearing devices are safe options for hearing rehabilitation in patients with the appropriate indications. Loading at 3 weeks did not affect the stability of either implant.

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Keywords Bone-anchored hearing aid · Bone-anchored hearing system · Baha · Ponto · Bone conduction · Implant stability quotient (ISQ) · Resonance frequency analysis (RFA) · Early loading · Implant survival · Quality of life

Introduction

Percutaneous osseointegrated titanium implants have been used to attach vibrating bone conduction devices to the temporal bone since 1977 [1]. Both implants and devices, as well as the indications for application, have been studied extensively [2, 3]. The clinical outcomes of these implants have been reported in large populations: long-term implant survival rates vary between 81.5 and 98.4 %, while complications generally involve soft tissue inflammation [4–6]. Severe complications are rare [4, 5].

Recently, the designs of these bone-anchored hearing implants have evolved to include wider diameters, based on the known advantages of wider implants in dentistry [7]. These 4.5-mm-wide implants provide a larger contact surface between the implant and the bone compared to the 3.75-mm-wide implants of the previous generation, which results in higher reported implant stability quotients (ISQ) and high implant survival rates [8, 9]. Moreover, wider implants appear to have higher levels of initial stability, which allows for early loading of the implant with the device. Loading wider implants has been reported to be safe at 3 weeks after surgery [10].

The current randomized controlled clinical trial investigated ISQ, implant survival, and soft tissue tolerability of a new wide implant in comparison to a previous generation implant in the first 6 months after implantation. Early loading of both implants was studied, with all implants loaded at 3 weeks. Subjective benefits of the bone

The Laryngoscope

The SoundBite Hearing System: Patient-Assessed Safety and Benefit Study

Richard K. Gurgel, MD; Clough Shelton, MD

Objectives/Hypothesis: To determine the safety and efficacy of the SoundBite for patients over a 6 month period of use.

Study Design: Prospective, multisite, nonrandomized patient enrollment with outcomes based on audiometric profile and self-reported assessment.

Methods: Patients with single-sided deafness were eligible for the study. Patients were fit with the standard SoundBite sound transducer and were asked to wear the device regularly for 6 months. At the end of the trial period, patients completed both a self-assessment and the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaires.

Results: Thirty-four subjects completed the study. Mean APHAB scores improved significantly for ease of communication ($P < 0.001$), background noise ($P < 0.001$), reverberation ($P < 0.001$), and global benefit ($P < 0.001$). Patients reported high rates of auditory benefit in a variety of listening situations and high rates of overall satisfaction with the device. One adverse event with a superficial mouth sore was reported and resolved after appropriate dental care. Twelve patients (35%) reported acoustic feedback. In six of these patients, the feedback resolved after device adjustment.

Conclusion: The SoundBite is a new hearing prosthesis that delivers bone conduction energy. It offers advantages over traditional osseointegrated devices that require surgical placement. Patient satisfaction with the device after 6 months of regular use is high. The SoundBite provided improvement in ease of communication, hearing in background noise, sound reverberation, and an overall global hearing benefit. Acoustic feedback is the most commonly reported problem with the SoundBite, and this is minimized with proper fitting.

Key Words: SoundBite, bone anchored hearing aid, Baha, single-sided deafness.

Level of Evidence: 2c.

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INTRODUCTION

Bone conduction is an effective way to deliver sound to the inner ear. When compared to transcutaneous stimulation, direct coupling of acoustic energy to bone provides improved aided thresholds, speech-in-noise, and overall hearing performance.[1–3] In 1981, Tjellstrom et al. provided one of the early clinical reports of using an osseointegrated titanium implant in the temporal bone, later known as the bone anchored hearing aid.[4] More recently, a new device called the SoundBite (SonitusMedical, Inc., San Mateo, CA) has been developed as an alternative to percutaneous titanium implants.[5]

The SoundBite utilizes a behind-the-ear (BTE) transmitter that is connected to a microphone placed in the ear canal of the hearing-impaired ear (Fig. 1). The BTE module sends a signal to a custom made in-the-mouth (ITM) transducer that couples the buccal surface of the maxillary molars to a piezoelectric bone stimulator capable of conducting sound (Fig. 1). Reports have shown the efficacy of the SoundBite in amplifying sounds over a wide range of frequencies (250-12,000 Hz) and improving hearing in noise.[5,6] The purpose of this study was to assess the safety and efficacy of the SoundBite for patients over a 6 month period of use.

MATERIALS AND METHODS

Seven study sites located in Arizona, California, Florida, Michigan, Texas, and Utah enrolled patients in the study. To reflect a broad population of users, the sites were chosen to represent small- and medium-sized private practices; hospital-based practices; and a tertiary care, academic medical center. Institutional review board approval was obtained for each site. Patients who had already elected to use the SoundBite were then subsequently informed and enrolled in the study. There was no randomization of the subjects as all wore the same SoundBite device. Patients were financially reimbursed a nominal amount ($100 paid by Sonitus medical) for completing the outcome questionnaires, but were personally responsible for all other medical, dental, travel, and device costs.

All medical, dental, and audiologic services were provided by licensed professionals. Adult patients with unilateral, acquired sensorineural hearing loss of any etiology were eligible for enrollment. In the better hearing ear, a four-tone (500, 1000, 2000, and 3000 Hz) pure tone average (PTA) of $\leq$ 25dB with no

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ORIGINAL PAPER

Simulation of the power transmission of bone-conducted sound in a finite-element model of the human head

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Abstract
Bone conduction (BC) sound is the perception of sound transmitted in the skull bones and surrounding tissues. To better understand BC sound perception and the interaction with surrounding tissues, the power transmission of BC sound is investigated in a three-dimensional finite-element model of a whole human head. BC sound transmission was simulated in the FE model and the power dissipation as well as the power flow following a mechanical vibration at the mastoid process behind the ear was analyzed. The results of the simulations show that the skull bone (comprises the cortical bone and diploë) has the highest BC power flow and thereby provide most power transmission for BC sound. The soft tissues was the second most important media for BC sound power transmission, while the least BC power transmission is through the brain and the surrounding cerebrospinal fluid (CSF) inside the cranial vault. The vibrations transmitted in the skull are mainly concentrated at the skull base when the stimulation is at the mastoid. Other vibration transmission pathways of importance are located at the occipital bone at the posterior side of the head while the transmission of sound power through the face, forehead and vertex is minor. The power flow between the skull bone and skull interior indicate that some BC power is transmitted to and from the skull interior but the transmission of sound power through the brain seem to be minimal and only local to the brain–bone interface.

Keywords Bone conduction sound · Finite-element model · Power transmission

1 Introduction

Bone-conducted (BC) sound produces an auditory sensation when vibrations stimulate the inner ear via mechanisms different from ordinary air conduction (AC) transmission through the ear canal and middle ear (Stenfelt and Goode 2005b). Even if BC sound is transmitted in the bone of the skull, the outer and middle ear may contribute to the final auditory perception (Stenfelt et al. 2002; Stenfelt et al. 2003). However, the main distinction between AC and BC sound is that BC sound has a dominant sound power transmission through the skull bone (Eeg-Olofsson et al. 2008; Stenfelt and Goode 2005a; Eeg-Olofsson et al. 2013), the soft tissues, or the interior of the skull (Sim et al. 2016; Roosli et al. 2016).

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Hearing by BC is usually described as sound power transmitted through the body (Stenfelt 2013). But the exact pathways conveying the sound power have not been clarified. For example, with BC stimulation at the mastoid, the sound transmission to the contralateral ear can be transmitted through the thin bony shell of the cranial vault, through the thicker skull base, or as a sound pressure through the interior of the skull. Therefore, an investigation of the sound power transmission could result in a better understanding of BC hearing in the human. However, vibratory power transmission in a living human or a cadaver head is difficult to measure. One possible solution is to compute the power transmission using a simulation model for BC sound.

Recently, a three-dimensional finite-element (FE) model of the whole human head was developed by Chang et al. (2016). The model was reconstructed from the anatomy of an adult female head through the Visible Human Project© (http://vhnet.nlm.nih.gov/). The dynamic response of the whole head FE model was validated by comparing the simulation results with the experimental data obtained in cadaver heads and living humans (Eeg-Olofsson et al. 2008; Eeg-Olofsson et al. 2011; Håkansson et al. 1986; Stenfelt

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The role of miniaturization in the evolution of the mammalian jaw and middle ear

Stephan Lautenschlager[1,2]*, Pamela G. Gill[1,3], Zhe-Xi Luo[4], Michael J. Fagan[5] & Emily J. Rayfield[1]*

The evolution of the mammalian jaw is one of the most important innovations in vertebrate history, and underpins the exceptional radiation and diversification of mammals over the last 220 million years[1,2]. In particular, the transformation of the mandible into a single tooth-bearing bone and the emergence of a novel jaw joint—while incorporating some of the ancestral jaw bones into the mammalian middle ear—is often cited as a classic example of the repurposing of morphological structures[3,4]. Although it is remarkably well-documented in the fossil record, the evolution of the mammalian jaw still poses the paradox of how the bones of the ancestral jaw joint could function both as a joint hinge for powerful load-bearing mastication and as a mandibular middle ear that was delicate enough for hearing. Here we use digital reconstructions, computational modelling and biomechanical analyses to demonstrate that the miniaturization of the early mammalian jaw was the primary driver for the transformation of the jaw joint. We show that there is no evidence for a concurrent reduction in jaw-joint stress and increase in bite force in key non-mammaliaform taxa in the cynodont–mammaliaform transition, as previously thought[5–8]. Although a shift in the recruitment of the jaw musculature occurred during the evolution of modern mammals, the optimization of mandibular function to increase bite force while reducing joint loads did not occur until after the emergence of the neomorphic mammalian jaw joint. This suggests that miniaturization provided a selective regime for the evolution of the mammalian jaw joint, followed by the integration of the postdentary bones into the mammalian middle ear.

The mammalian jaw and jaw joint are unique among vertebrates[6]. The craniomandibular jaw joint of non-mammalian vertebrates is formed between the quadrate and articular bones, whereas mammals evolved a novel jaw hinge between the squamosal and dentary bones—the secondary or temporomandibular jaw joint[1–4]. The evolutionary origins of this morphological transformation involved a suite of osteological modifications to the feeding and auditory systems that occurred over a period of 100 million years during the Late Triassic and Jurassic across the cynodont–mammaliaform transition[9,10]. The tooth-bearing dentary bone increased in size relative to the postdentary elements, eventually transforming the seven-bone lower jaw in pre-mammalian cynodonts (hereafter referred to as cynodonts) to a single-bone lower jaw in modern mammals; parallel to this simplification of the mandible, the integration of elements of the ancestral craniomandibular jaw joint into the ossicular chain led to a unique middle and inner ear morphology capable of more sensitive sound detection[11,12]. New fossil information has suggested that a definitive mammalian middle ear (DMME) evolved independently in at least three mammalian lineages by detachment from the mandible, but the emergence of a secondary jaw joint is a key innovation that unites all mammaliaforms[9,13]. However, a central question exists as to how, during this transformation, the jaw hinge remained robust enough to bear strong mastication forces while the same bones were becoming delicate enough to be biomechanically viable for hearing[3,5,10].

The stepwise acquisition of morphological features leading to the emergence of the temporomandibular jaw joint is exceptionally well-documented in the fossil record, by a series of transitional taxa that illuminates the evolutionary dynamics involved[4]. While still appearing to function as a jaw joint and viable for sound transmission in cynodonts (for example, *Thrinaxodon liorhinus*, *Probainognathus* and *Probelesodon sanjuanensis*), the postdentary bones gradually reduced in size and shifted away from the jaw joint—probably for more sensitive hearing[10,12]. This trend resulted in all basal mammaliaforms (for example, *Sinoconodon rigneyi* and *Morganucodon oehleri*) possessing a remarkable 'dual jaw joint' with two seemingly functional joints: a quadrate–articular joint medial to a mammalian dentary condyle and squamosal glenoid hinge[11,13]. More derived groups and crown mammals eventually lost the ancestral quadrate–articular joint. In addition to fossil evidence, this sequence of events was identified historically in embryonic stages of living mammals[14,15] and recent morphogenetic studies, gene patterning and regulatory networks have further elucidated the development of these structures[16,17]. Previous studies have theorized that muscle reorganization reduced load at the jaw joint[6,10], yet these claims have not been tested in fossil taxa and experimental studies of extant mammals reveal that the jaw joint usually experiences net compressive loading[18,19]. The modification of the mandible and the emergence of a novel jaw joint and middle ear therefore represent an intriguing problem. This is especially puzzling when all the evidence points towards modifications for increased jaw muscle force, consolidation of cranial bones, increased complexity of sutures and supposedly stronger skulls during mammalian evolution[1,5].

Here we integrate a suite of digital reconstruction, visualization and quantitative biomechanical modelling techniques to test the hypothesis that reorganization of the adductor musculature and reduced stress susceptibility in the ancestral jaw joint facilitated the emergence of the mammalian temporomandibular jaw joint. Applying finite element analysis, we calculated bone stress, strain and deformation to determine the biomechanical behaviour of the mandibles of six key taxa across the cynodont–mammaliaform transition (Fig. 1). These analyses were supplemented by multibody dynamics analysis to predict bite forces and joint reaction forces. Results from the combined analyses demonstrate that during simulated biting there is no evidence for the reduction of stresses (von Mises, tensile and compressive) in the jaw joint (craniomandibular jaw joint and/or temporomandibular jaw joint) across the cynodont and mammaliaform taxa that we studied (Figs. 2, 3, Extended Data Figs. 1, 3). This was found to be the case for unilateral and bilateral biting simulations, regardless of the working and balancing side joint. However, bite position appears to have a moderate effect on joint stresses—particularly compression—and stress increases as the bite point moves anteriorly along the tooth row. This is consistent with experimental data for extant mammals, in which incisor biting results in the highest joint loads[20]. Similarly, the results of multibody dynamics analysis show that absolute joint reaction forces are not reduced as the jaw joint undergoes morphological transformation (Figs. 2, 3), whereas relative bite forces—the ratio between muscle force and bite

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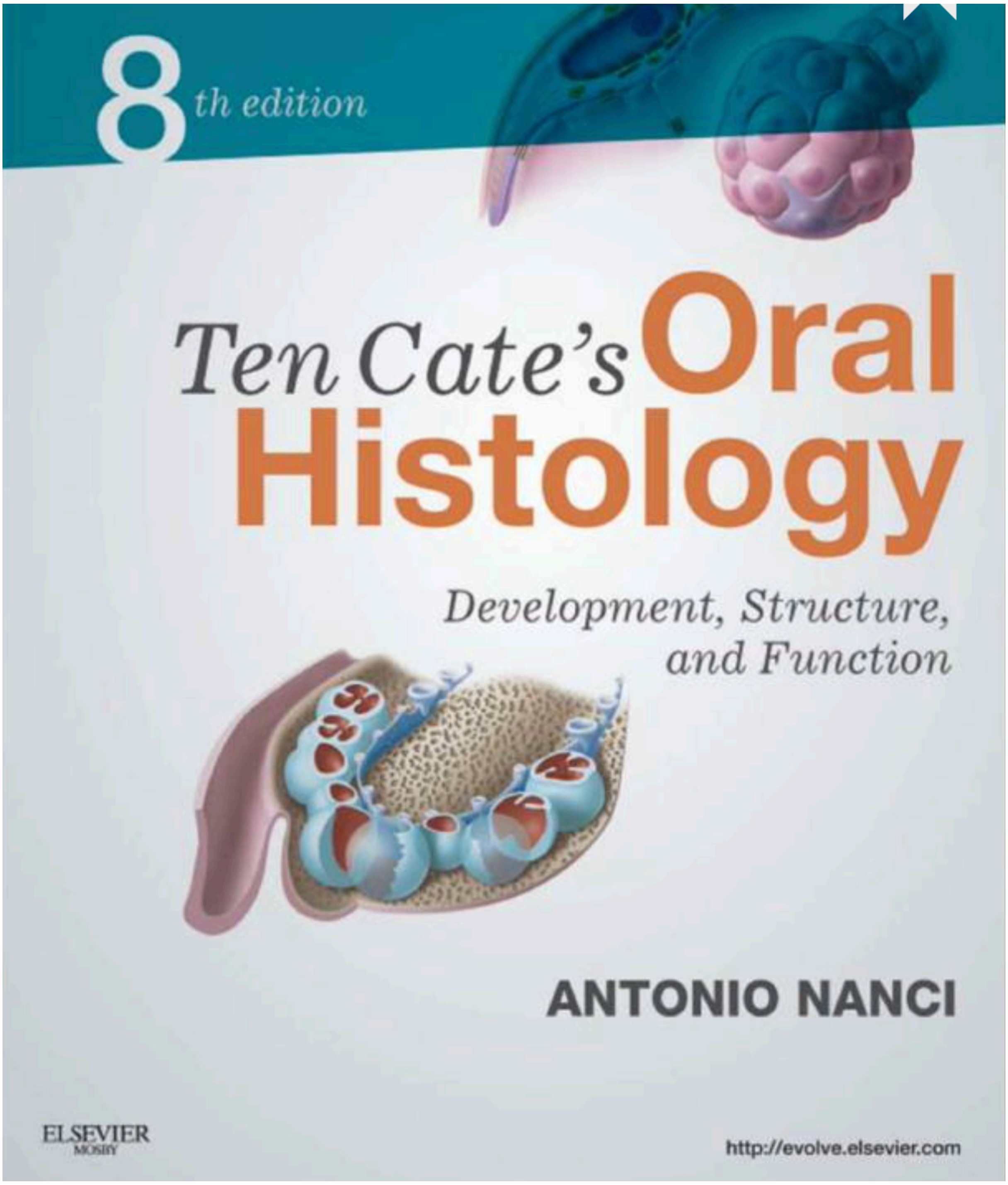
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ORIGINAL ARTICLE

The Meckel's cartilage in human embryonic and early fetal periods

Marzena Wyganowska-Świątkowska · **Agnieszka Przystańska**

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Abstract The Meckel's cartilage itself and the mandible are derived from the first branchial arch, and their development depends upon the contribution of the cranial neural crest cells. The prenatal development of the Meckel's cartilage, along with its relationship to the developing mandible and the related structures, were studied histologically in human embryos and fetuses. The material was obtained from a collection of the Department of Anatomy, and laboratory procedures were used to prepare sections, which were stained according to standard light-microscopy methods. The formation of the Meckel's cartilage and its related structures was observed and documented. Some critical moments in the development of the Meckel's cartilage are suggested. The sequential development of the Meckel's cartilage started as early as stage 13 (32 days) with the appearance of condensation of mesenchymal cells within the mandibular prominence. During stage 17 (41 days), the primary ossification center of the mandible appeared on the inferior margin of the Meckel's cartilage. The muscular attachments to the Meckel's cartilage in embryos were observed at stage 18 (44 days). Their subsequent movement into the developing mandible during the 10th week seemed to diminish the role of the Meckel's cartilage as the supportive core; simultaneously, the process of regression within the cartilage was induced. During the embryonic period, the bilateral Meckel's cartilages were in closest contact at the posterior surface of their superior margins, preceding formation of the symphyseal cartilage at this site. The event sequence in the development of the Meckel's cartilage is finally discussed.

Keywords Mandible · Cartilage · Morphogenesis

Introduction

During the last several decades, a number of studies have proved the importance of the Meckel's cartilage in the development of the mandible. There has been immense interest in the morphogenesis of the human mandibular process among anatomists, embryologists, and clinicians. This topic gained increasing popularity primarily due to the Meckel's cartilage and its contribution to the growth and formation of the mandibular bone. It is reported that many factors [i.e., connective tissue growth factor (CTGF), transforming growth factor β (TGF-β), fibroblast growth factor (FGF)] play a critical role in the regulation of the Meckel's cartilage development (Chai et al. 2000; Ito et al. 2002; Shimo et al. 2004). Many craniofacial abnormalities include defects in the formation of the Meckel's cartilage and the mandible. Trumpp et al. (1999) documented a serious defect in the proper development of the first branchial arch resulting in a rudimentary mandible as a result of inactivation of the *FGF8* gene.

Genetic experiments have proved the important role of epithelial–mesenchymal interactions in the development of the mandibular process. It has been shown that *Tgfb*, *Pitx1*, *Tbx1*, *Sox9*, and *Runx2* are necessary for normal mandible development (Lanctot et al. 1999; Miettinen et al. 1999; Satokata et al. 2000).

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The mandible and its foramen: anatomy, anthropology, embryology and resulting clinical implications

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The aim of this paper is to summarise the knowledge about the anatomy, embryology and anthropology of the mandible and the mandibular foramen and also to highlight the most important clinical implications of the current studies regarding anaesthesia performed in the region of the mandible. An electronic journal search was undertaken to identify all the relevant studies published in English. The search included MEDLINE and EMBASE databases and years from 1950 to 2012. The subject search used a combination of controlled vocabulary and free text based on the search strategy for MEDLINE using key words: 'mandible', 'mandibular', 'foramen', 'anatomy', 'embryology', 'anthropology', and 'mental'. The reference lists of all the relevant studies and existing reviews were screened for additional relevant publications. Basing on relevant manuscripts, this short review about the anatomy, embryology and anthropology of the mandible and the mandibular foramen was written. (Folia Morphol 2013; 71, 4: 285–292)

Key words: mandible, human anatomy, inferior alveolar nerve block, mandibular foramen, mental protuberance

INTRODUCTION

The aim of this paper is to summarise the knowledge about the anatomy, embryology and anthropology of the mandible and the mandibular foramen, and also to highlight the most important clinical implications of the current studies regarding anaesthesia performed in the region of the mandible.

METHODS

An electronic journal search was undertaken to identify all the relevant studies published in English. This search included MEDLINE and EMBASE databases and years from 1950 to 2012. The subject search used a combination of controlled vocabulary and free text based on the search strategy for MEDLINE using the key words: 'mandible', 'mandibular', 'foramen', 'anatomy', 'embryology', 'anthropology', and 'mental'. The reference lists of all the relevant studies and existing reviews were screened for additional relevant publications.

Each publication was initially assessed for relevance using data presented in the abstract. When the abstract was not available or failed to provide sufficient information, a reprint of the full paper was obtained. When the papers or abstracts reported different stages of clinical trial, only the longer-term study was included in the review. When both the full paper and the abstract were published based on data from the same clinical trial, only the full paper was included.

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MANDIBLE — CLINICALLY REVISITED

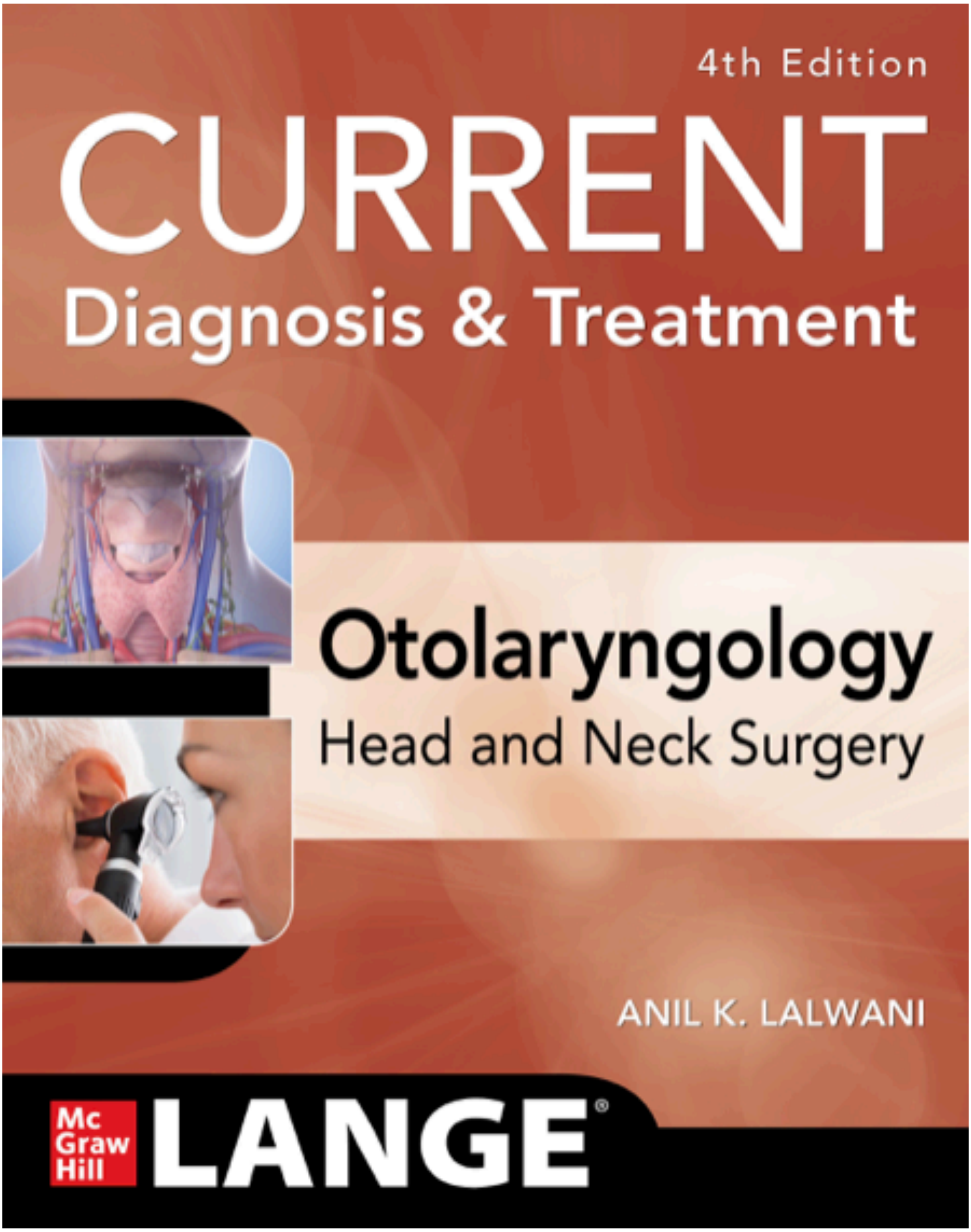
Abstract: Based on the current literature authors revised anatomical and clinical datas considering the mandible.

Key words: mandible, anatomy, development, nerve supply.

INTRODUCTION

Composition of the mandible resembles somehow the structure of flat bones. It consists of central cancellous bony tissue and surrounding compact substance. Compact substance hinders penetration of the anesthetic. Body of the mandible is much thicker than the ramus — it is the thickest at a level of oblique and mylohyoid lines. Mentioned locations are reported to the greatest burden during upper jaw pressure. Composition of the compact substance is specially tight, and both external and internal laminae are thick at their connections on the mandibular base. Between factors predisposing such shape one can list the ligaments, which insertions are located on this bone [1–3]. Internal (lingual) walls of dental alveoli are significantly thicker than external ones (labial and buccal respectively), apart from the dental alveolus of the third molar tooth where the buccal wall seems to be thicker [1, 4].

Mandibular ramus is a quadrangular bony plate which originates bilaterally from the posterior end of the body. Anatomically it has two surfaces and two processes. Lateral surface of mandibular ramus is rough in its inferior part — possessing the masseteric tuberosity, where masseter muscle inserts. Medial aspect of mandibular ramus shows mandibular foramen. One can see accessory foramina here [5, 6]. Mandibular foramen is limited anteriorly by little bony spicule — lingual. This projection and its vicinity serve as an attachment for sphenomandibular ligament [7]. Lingula is palpable during inspection of the oral cavity through the oral mucosa. It indicates the direction of the needle position during performing anesthesia of the lower teeth [8].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Are Temporomandibular Disorders and Tinnitus Associated?

Aline Dantas Diógenes Saldanha, D.D.S., M.Sc.; Priscila Brenner Hilgenberg, D.D.S., M.Sc.; Lívia Maria Sales Pinto, D.D.S., M.Sc.; Paulo Cesar Rodrigues Conti, D.D.S., Ph.D.

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ABSTRACT: The current study aimed to research the prevalence of temporomandibular disorders (TMD) in patients with subjective tinnitus, as compared to controls, and the association between symptoms of TMD, tinnitus, and chronic pain. Two hundred patients were divided into two groups, according to the presence (experimental) or not (control) of subjective tinnitus. The subgroups were determined according to the RDC/TMD criteria. The Pain Pressure Threshold (PPT) values of the masseter and temporalis muscles were recorded bilaterally, and a Visual Analog Scale (VAS) was used to address subjective pain. The most prevalent TMD subgroups in the tinnitus patients ($p<0.05$) were myofascial pain with limited opening (39.0%), disc displacement with reduction (44.33%), and arthralgia (53.54%). The severity of tinnitus was significantly associated with the severity of chronic pain ($p=.000$). The PPT values were lower ($p>0.05$), while the Visual Analog Scale (VAS) was statistically higher ($p=.000$) for the tinnitus patients. These results suggest that an association exists between TMD and subjective tinnitus.

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According to the American Academy of Orofacial Pain, temporomandibular disorders (TMD) encompass several clinical complaints involving the masticatory muscles, the temporomandibular joint (TMJ), associated structures, or all of these.[1]

The symptomatology of the TMD is complex, involving mandibular, head and facial pain, among several other symptoms, such as joint noises and jaw locking. Studies also suggest a relationship between TMD and otologic symptoms, including otalgia, tinnitus, decreased auditive accuracy, sensation of auricular plenitude (fullness), hyperacusia, dizziness, and vertigo.[2,3] Tinnitus (ringing in the ears) refers to the perception of sound, regardless of an external source.[4,5]

The first publication reporting the association of otological symptoms and TMD dates from 1934 and proposed that loss of posterior dental support would predispose subjects to a shift of the mandibular condyle towards the posterior part of the tympanum, resulting in compression of the eustachian tube, of the auricular-temporal nerve, and/or of the chorda tympani. This neural damage could cause auditive loss, as well as other otological symptoms.[6]

The middle ear is anatomically and ontogenetically related to the TMJ. In 1962, a ligament connecting TMJ

TEMPOROMANDIBULAR JOINT DEVELOPMENT AND FUNCTIONAL DISORDERS RELATED TO CLINICAL OTOLOGIC SYMPTOMATOLOGY

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SUMMARY – Temporomandibular disorders (TMDs) are a form of musculoskeletal pain of the temporomandibular joint (TMJ) and/or masticatory muscles of nonspecific etiology. In this study, the relationship between embryonic and anatomic-topographic similarities of the TMJ and the ear was analyzed, i.e. secondary otologic symptoms that can be closely connected to TMJ disorder. Nonspecific otologic symptoms are not primary diagnostic symptoms of TMD, but may cause diagnostic confusion due to patients' inability to correctly locate the origin of pain. The most common otologic symptoms that can be related to TMDs are otalgia, tinnitus and vertigo. Otorhinolaryngologists have to differentiate between primary otologic symptoms and those caused by TMJ disorders. In TMD diagnosis, manual techniques are used to determine the arthrogenic or myogenic form, whereas in the diagnosis of arthrogenic disorders magnetic resonance imaging is indicated as the highly specific imaging method of joint disk and osteoarthritic changes. Symptomatic treatments for TMD as well as the etiologic diagnosis of the pain require multidisciplinary cooperation between dentists and medical specialists.

Key words: *Temporomandibular joint disorders; Earache; Tinnitus; Magnetic resonance imaging; Diagnosis, differential*

Temporomandibular Disorders

Functional disorders including pain in the temporomandibular joint (TMJ) and/or masticatory muscles, pathologic sounds in TMJ and limited mouth opening are all called temporomandibular disorders (TMDs). Although they are major diagnostic symptoms, TMDs are not classified as a syndrome. Besides the ones mentioned, accompanying nonspecific otologic symptoms and tension-type headaches may also occur, thus definitive diagnosis cannot be given[1-3]. The prevalence of clinical symptoms in adult population is from 12% to 42.7% and the need for treatment from 3% to 9%[4-6].

TMDs are musculoskeletal disorders, which can be difficult to locate for patients, especially in an earlier stage. TMDs belong to a group of myogenic (tendomyopathies of masticatory muscles) and arthrogenic (discopathy, osteoarthritis of TMJ) disorders. Untreated acute pain can evolve into a chronic form and become a separate illness. Psychosocial factors, as in other musculoskeletal disorders, have a dominant role and therefore the clinical and radiological findings tend to be disproportionate to the symptoms[7-11].

The aim of this study was to analyze the interrelationship of otologic symptoms and TMD symptoms

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Tinnitus in patients with temporo-mandibular joint disorder: Proposal for a new treatment protocol

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Relationship between Otological Symptoms and TMD

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Bianca Lopes Cavalcante de Leão[1]
Paulo Francisco Arant Martins[1]
Adriana Bender Moreira de Lacerda[1]
Bianca Simone Zeigelboim[1]

Abstract

Background: Patients with any type of temporomandibular disorder (TMD) may have several symptoms in their temporomandibular joints, masticatory muscles and associated structures, and may have otological symptoms such as tinnitus, ear fullness, ear pain, hearing loss, hyperacusis, and vertigo, which may be due to the anatomical proximity between the temporomandibular joint, muscles innervated by the trigeminal nerve, and ear structures. Objective: This study found a prevalence of ear complaints described in the medical records of patients (n = 485) at the Center for Diagnosis and Treatment of the Temporomandibular Joint and Dental-Facial Functional Alterations at Tuiuti University of Paraná (CDATM/UTP), with TMD evaluated by the Research Diagnostic Criteria/Temporomandibular Disorders (RDC/TMD).

Method: After approval by the ethics committee were examined 485 medical records of patients of the CDATM/UTP, of both sexes a period of 2 years. The data analyzed were gender, age and the presence of reported otologic symptoms. The data were organized and subjected to statistical analysis using SPSS (IBM Statistic 20.0).

Results: The results showed a higher number of female patients between 41 and 50 years old. There was a prevalence of otological symptoms (tinnitus, deafness, dizziness, imbalance, and ear fullness) in 87% of TMD cases, regardless of sex and age. Tinnitus was the symptom with the highest prevalence (42%), followed by the ear fullness (39%).

Conclusion: These data support the correlation between temporomandibular disorders and otological symptoms, even without being caused directly by the ear.

Keywords: temporomandibular joint, tinnitus, ear ache, temporomandibular joint disorders, facial pain, dentistry.

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Temporomandibular disorders, otologic symptoms and depression levels in tinnitus patients

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SUMMARY The aim of this study was to determine the prevalence of signs and symptoms of temporomandibular disorders (TMD) and otologic symptoms in patients with and without tinnitus. The influence of the level of depression was also addressed. The tinnitus group was comprised of 100 patients with tinnitus, and control group was comprised of 100 individuals without tinnitus. All subjects were evaluated using the research diagnostic criteria for temporomandibular disorders (RDC/TMD) to determine the presence of TMD and depression level. Chi-square, Spearman Correlation and Mann–Whitney tests were used in statistical analysis, with a 5% significance level. TMD signs and symptoms were detected in 85% of patients with tinnitus and in 55% of controls ($P \leq 0{\cdot}001$). The severity of pain and higher depression levels were positively associated with tinnitus ($P \leq 0{\cdot}001$). It was concluded that tinnitus is associated with TMD and with otalgia, dizziness/vertigo, stuffy sensations, hypoacusis sensation and hyperacusis, as well as with higher depression levels.

KEYWORDS: temporomandibular joint disorder, tinnitus, earache, dizziness, depression

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Introduction

The American Academy of Orofacial Pain defines temporomandibular disorders (TMD) as a collective term that embraces a number of clinical problems that involve the masticatory muscles, the temporomandibular joint (TMJ) and associated structures. Jaw pain, earache, headache, limited function and associated features are commonly reported by patients with TMD. Otolaryngologic, neurological and vascular symptoms are also frequently found in such population (1). The most common otolaryngological symptoms associated with TMD are tinnitus, dizziness/vertigo, earache, hypoacusis sensation, hyperacusis and stuffy sensation (2).

The association between TMD and tinnitus is very well described in the literature (3–5), although a clear cause–effect relationship still could not be effectively revealed (6). There are several theories behind this association. The first one was proposed by Costen in 1934 (7) and suggested that changes in the position of the temporomandibular joints (TMJ) caused by the loss of posterior teeth and vertical dimension of occlusion (VDO) could increase the pressure over the ear structures and cause otologic symptoms. Another theory was hypothesised by Pinto in 1962 (8), who claimed finding a 'tiny-ligament', called disc-malleolar, responsible for the otologic symptoms in patients with TMD. Myrhaug, in 1964 (9), suggested that a muscular TMD could cause a secondary hypertone of the tensor tympani and tensor veli palate muscles, generating aural symptoms. The last but not least, there is a sensory-motor theory, which postulates that tinnitus modulation can occur by muscular contractions, such as when palpating myofascial trigger-points. There are several authors who also agree that tinnitus, dizziness and depression have the same initiating and perpetuating factors (10), such as emotional disturbances, humour, personality traits and attention, which can also modulate its perception (11–13). Tinnitus in patients with TMD is probably associated with an interaction between auditory and sensory-motor systems, and symptoms might also be

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Research Article

Association between Anatomical Features of Petrotympanic Fissure and Tinnitus in Patients with Temporomandibular Joint Disorder Using CBCT Imaging: An Exploratory Study

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Mandible displacement is known to correlate with otological conditions such as pain in the ear canal, hearing loss, or tinnitus. The present work aimed to determine the association between the displacement of the condyle in a temporomandibular joint, the structure and position of the petrotympanic fissure (PTF), and comorbid tinnitus in patients affected by temporomandibular joint and muscle disorder (TMD). We enrolled 331 subjects with TMD (268 women and 63 men). The average age of women was 40.8 ± 16.8 years (range 13–88), whereas the average age of the examined men was 38 ± 14 years (range 13–74). We performed imaging studies of the facial part of the skull in the sagittal plane using a volumetric imaging method and a large imaging field (FOV) of $17\,cm \times 23\,cm$. The habitual position of the mandible was determined and used as a reference. Based on the imaging results, we developed a classification for the topography and the structure of the petrotympanic fissure. Thirty-three TMD patients (about 10% of the sample) reported having tinnitus. These patients had PTF configurations characterized by a rear (36.59%) or intracranial-cranial (63.41%) condylar displacement of the temporomandibular joint. Our findings imply that the TMJ- and tinnitus-positive group of patients possibly represents a distinct phenotype of tinnitus. We concluded that for such patients, the therapeutic approach for tinnitus should include TMD treatment.

1. Introduction

Tinnitus is a subjective perception of sound without an external acoustic signal occurring due to inappropriate activation of the auditory cortex. Tinnitus may be perceived as unilateral or bilateral phantom sound and be either continuous or intermittent symptom [1] of various conditions, including the malfunction of auditory periphery [2]. Activation of the auditory cortex of tinnitus patients in silence has been documented during imaging studies using positron emission tomography (PET) or functional magnetic resonance imaging (fMRI) [3]. Tinnitus may be a symptom of many conditions, including presbyacusis, otosclerosis, chronic otitis media, ototoxicity, labyrinthitis, noise-induced hearing loss, and congenital disorders. Besides, diseases that directly or indirectly affect neurons of the auditory pathway (multiple sclerosis, vestibular schwannomas, meningiomas, stroke, intracranial hemorrhage, and head injuries) may also associate with tinnitus. Tinnitus patients have often compromised hearing thresholds and speech perception and generally have a lower health-related quality of life [4].

Furthermore, comorbid conditions such as insomnia, anxiety, difficulties with concentrating, or negative thinking

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OTOLOGY

Depression, Anxiety and Stress Scale in patients with tinnitus and hearing loss

Mohammed Abdel Motaal Gomaa · Manal Hassan Abo Elmagd · Mohammed Mohammed Elbadry · Rafeek Mohammed Abdel Kader

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Abstract The study was proposed to evaluate co-morbid depression, anxiety and stress associated with tinnitus patients. The study was done on 196 subjects: 100 patients suffering from subjective tinnitus associated with hearing loss (tinnitus group), 45 patients suffering from hearing loss only (hearing loss group) and 50 healthy subjects not suffering from tinnitus or hearing loss (control group); the age ranges from 20 to 60 years old. The studied sample was subjected to full ear, nose and throat examinations and audiological evaluation. Depression, Anxiety and Stress Scale (DASS) was developed by Levibond H and Levibond F to assess three self-report scales designed to measure the negative emotional status of depression, anxiety and stress. All patients and control group were evaluated by DASS. (1) Depression: males were affected more than females. All patients over 60 years were affected by depression. The duration of tinnitus seems correlating with the severity of depression. Only 2 patients (4.3 %) of the hearing loss group suffer from depression. (2) Anxiety: 90 % of males suffer from anxiety as compared to 83.3 % females. The age group 20–29 years old suffers more than other age groups. Only 4 patients (8.7 %) of hearing loss group suffer from anxiety. (3) Stress: females seem to be affected by the stress (76.7 %) more than males (67.5). Patients in age group 30–39 suffer the most from the disease. There is a direct correlation between duration of tinnitus and severity of stress. No one of the hearing loss group suffers from stress. In conclusion, depression, anxiety and stress should be taken into consideration in the treatment of patients suffering from tinnitus.

Keywords Tinnitus · Depression · Anxiety and stress

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Introduction

Tinnitus is an auditory perception characterized by experience of sound in the ear or head with absence of external acoustic stimulation [1]. The intimate relation of the auditory tract and the limbic system may lead to stress reaction with other cognitive disorders [2]. About 10 % of the population experience tinnitus, with marked heterogeneity in etiology, perception and extent of psychological disorders among these people [3]. Tinnitus can be associated with virtually all disorders affecting the auditory system. Numerous studies report that the pitch of the tinnitus sensation matches the region of the hearing loss [4]. The "US Veterans Administration Benefits Report" ranked tinnitus as the second most prevalent service-related disability [5].

The aim of our study is to use Depression, Anxiety and Stress Scale (DASS) in evaluating patients that suffer from tinnitus associated with hearing loss.

Patients and methods

The study was approved by Research Ethics Committee of Minia University Hospital. All patients signed a consent to

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Tinnitus Patients Suffering from Anxiety and Depression: A Review

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Abstract

Objectives: To review literature on the link between depression and anxiety in patients suffering from tinnitus. **Method:** A systematic review of published English-language literature was performed using PubMed, Ovid, and Cochrane databases. **Results:** Of the 56 eligible abstracts 15 were chosen to be included in the review. All articles showed an association of depression and anxiety in tinnitus patients. **Conclusions:** Because of the strong association between tinnitus, depression, and anxiety- all tinnitus patients should be screened for psychiatric disorders. Treatment for these complex conditions should involve a multidisciplinary team with cognitive behavioral therapy and possible pharmacological therapy.

Keywords: tinnitus, depression, anxiety, stress.

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It's time we listened to our teeth: The SoundBite hearing system

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The SoundBite hearing system (Sonitus Medical, San Mateo, Calif) allows people with single-sided deafness to wear an intraoral device and a small microphone in the deaf ear to regain lost hearing. A piezoelectric activator in a small removable unilateral oral appliance conducts sound through the bone via the teeth to the good ear. The goal of this article is to introduce the SoundBite, a new bone-conduction hearing device, to dentists and orthodontists. (Am J Orthod Dentofacial Orthop 2010;138:666-9)

Perhaps you remember old stories about people hearing sounds in their teeth when they got new fillings or braces. In 1942, Lucille Ball discussed hearing radio broadcasts through her teeth with her friends Ethel Merman and Buster Keaton at MGM Studios. That story ended up in a Cole Porter musical and various sitcoms over the years. It is no longer just a Hollywood legend.

Sound can travel along 2 pathways—air conduction and bone conduction. Dentists know that moving the jaw and clenching the teeth can play a part in the way we perceive sound. Place a forefinger into each ear; then open and close your mouth. As you open, you can clearly feel the condyle of the mandible moving and changing the size of the external ear canal. You can hear your own teeth tap together. We hear that tapping through bone conduction to the ear. The oral structures are close to the auditory structures.

A brief review of the ear is in order. The ear consists of an outer ear, a middle ear, and an inner ear. Hearing occurs when sound vibrations strike the eardrum, the thin membrane between the outer and middle parts of the ear. The auditory ossicles vibrate, and the footplate of the stapes moves at the oval window. Movement of the oval window causes the fluid inside the scala vestibuli and the scala typani to move. Fluid movement against the cochlear duct sets off nerve impulses, which are carried to the brain via the cochlear nerve.

Although dentists are not involved in the health of the ears, as health care professionals, we use our ears every day to help diagnose our patients and manage our staff and our businesses. Many of us have treated patients with hearing loss, and more than likely we will eventually have some level of hearing loss. Dentists in general are prone to hearing loss in the sound frequencies associated with the air turbine hand pieces that we use daily.[1]

It is estimated that single-sided deafness (SSD) afflicts almost 9 million people in the United States alone.[2] SSD is the complete or significant loss of hearing in 1 ear. SSD can be associated with tinnitus and affects the way sound is perceived. SSD affects sufferers in different ways and can be debilitating. The inability to determine the direction or point of origin of a sound can make even the simplest day-to-day tasks such as crossing the road, cycling, and jogging both difficult and dangerous. But by far the biggest obstacle for SSD sufferers is socializing in large groups or noisy environments. In these circumstances, many sufferers feel excluded because they miss out on conversations, whereas others worry that they will appear ignorant or rude if they do not hear a question. There is a constant need to turn the good ear toward the sound; this requires unusual movements of the head, and some SSD sufferers find it embarrassing.

SOUNDBITE TECHNOLOGY

Sonitus Medical has developed an intraoral device called the SoundBite hearing system. SoundBite is different from conventional hearing aids, which use air conduction to simply turn up the volume of sound traveling into the ear. Conventional hearing aids require a functional ear. As a bone-conduction device, the SoundBite hearing system does not require a functional middle or outer ear to deliver sound. The SoundBite hearing system is designed to allow sound to travel via the teeth, through the bones, to both cochleae, bypassing the middle and outer ears entirely. By using

The author is a consultant to Sonitus Medical. He is compensated for this work on clinical trials, and he has an option to purchase stock in the company.

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Fisiología de la estimulación sonora por vía ósea y la importancia de la transmisión de las frecuencias agudas por vía ósea

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Se considera que el fenómeno de la transmisión de los sonidos por vía ósea no es tan simple como que únicamente la vibración de los huesos del cráneo pone en movimiento los líquidos laberínticos. Se conoce que esta energía mecánica se reparte en el oído externo, el medio y el interno, y es difícil precisar cuál es la contribución de cada una de estas partes al total de la conducción.
La inercia de los fluidos cocleares es la contribución más importante a la audición por vía ósea, la inercia de los huesecillos contribuye en la conducción de las frecuencias medias, mientras que la compresión de las paredes cocleares influye en la conducción de las frecuencias agudas.

Palabras clave: Fisiología de la audición. Estimulación acústica vía ósea. Hipoacusia de transmisión.

Physiology of bone conduction acoustic stimulation and the importance of high-frequency bone conduction
The phenomenon of bone-conducted sound transmission involves more than just vibration of the skull bones to induce movement of the labyrinthine fluid. This mechanical energy is known to be distributed through the outer, middle and inner ear and identifying the precise contribution of each of these parts to total conductance is difficult. Cochlear fluid inertia is the most important contributing factor to bone-conduction hearing, inertia of the ossicles plays a role in medium-frequency conduction, while cochlear wall compression plays a role in high frequencies.

Key words: Physiology of audition. Bone conduction acoustic stimulation. Conductive hearing loss.

INTRODUCCIÓN

Es conocido que los sonidos se pueden transmitir por materiales sólidos, y también que el ser humano es capaz de percibir sonidos cuando los huesos del cráneo están sometidos a una vibración. Cuando una fuente sonora es aplicada directamente sobre estos huesos, sus propiedades fibroelásticas permiten que el sonido viaje a través de él por vibración, de forma que se estimulan las estructuras adecuadas para desencadenar la sensación sonora.

Este fenómeno, denominado transmisión de sonidos por vía ósea, es ampliamente conocido y aplicado para la localización topográfica de la hipoacusia. De una forma sencilla y rápida, mediante la realización de una audiometría tonal liminar o una exploración acumétrica, podemos distinguir entre hipoacusia de transmisión y neurosensorial.

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También, desde hace varias décadas, se ha aprovechado este fenómeno para el tratamiento de casos de hipoacusia de transmisión de etiología relacionada con procesos otológicos crónicos, con o sin intervención quirúrgica, o en casos de deformaciones congénitas de oído externo o medio. Se han empleado transductores, acoplados a una diadema, una gafa auditiva o a un dispositivo de osteointegración, para la corrección del déficit auditivo en relación con estas alteraciones.

El conocimiento de sus aplicaciones en la actividad clínica diaria no es parejo al de la forma en que se desarrolla este fenómeno. Diferentes trabajos de investigación intentan profundizar en las bases fisiológicas de su origen, y en los últimos años se han desarrollado, de forma importante, sus aplicaciones clínicas en oídos patológicos mediante el desarrollo de dispositivos osteointegrados de amplificación que mejoran las expectativas que nos ofrece este fenómeno en el tratamiento de algunos tipos de trastornos auditivos.

No es fácil aplicar los trabajos de investigación en animales de experimentación a la clínica debido a las importantes diferencias en las geometrías y densidades de las estructuras craneales entre especies, así como en las localizaciones del oído interno en la densidad de las estructuras óseas, diferencias que dificultan la traslación de estos resultados a la clínica diaria.

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Bone-Conducted Sound: Physiological and Clinical Aspects

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Objective: The fact that vibration of the skull causes a hearing sensation has been known since the 19th century. This mode of hearing was termed hearing by bone conduction. Although there has been more than a century of research on hearing by bone conduction, its physiology is not completely understood. Lately, new insights into the physiology of hearing by bone conduction have been reported. Knowledge of the physiology, clinical aspects, and limitations of bone conduction sound is important for clinicians dealing with hearing loss and is the purpose of this review.
Data Sources: The data were compiled from the published literature in the areas of clinical bone conduction hearing, bone conduction hearing aids, basic research on bone conduction physiology, and recent research on bone conduction hearing from our laboratory.
Conclusion: Five factors contributing to bone conduction hearing have been identified: 1) sound radiated into the external ear canal, 2) middle ear ossicle inertia, 3) inertia of the cochlear fluids, 4) compression of the cochlear walls, and 5) pressure transmission from the cerebrospinal fluid. Of these five, inertia of the cochlear fluid seems most important. Bone conduction sound is believed to reflect the true cochlear function; however, certain conditions such as middle ear diseases can affect bone conduction sensitivity, but less than for air conduction. The bone conduction route can also be used for hearing aids; since the bone conduction route is less efficient than the air conduction route, bone conduction hearing aids are primarily used for hearing losses where air conduction hearing aids are contraindicated. **Key Words:** Bone conduction—Conductive hearing loss—Tuning forks—Occlusion effect—Hearing testing—Hearing aids.

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The fact that humans can perceive sound when the bones of the skull are set into vibration has been known for many years and has primarily been used during the last two centuries to distinguish between the conductive and sensorineural components of a hearing impairment. This phenomenon is normally referred to as hearing by bone conduction (BC) or BC sound.

Stimulation of the Basilar Membrane?

One of the fundamental questions of BC sound was whether it was a cochlear stimulation or a stimulation of some other end organ. The first one to address this question was von Békésy, whose hypothesis was the following: If a sound transmitted by either air conduction (AC) or BC stimulates the basilar membrane the same way, they should be able to cancel each other if they end up with the same amplitude but 180 degrees out of phase. He was able to conduct subjective cancellation of an AC tone with a BC tone at 0.4 kHz in one subject (1) Four years later, Wever and Bray (2) measured the cochlear microphonic in cats by both AC and BC sounds and found them similar—yet another indication that AC and BC stimulates the end organ in a similar way. Lowy (3) extended von Békésy's findings by canceling an AC tone with a BC tone over a frequency range from 0.25 to 3 kHz in animals while measuring the cochlear microphonics; Wever and Lawrence (4) extended this measurement to 0.1 to 15 kHz. Khanna et al. (5) found subjective cancellation of an AC 1-kHz tone by a BC 1-kHz tone over a range of 40 to 70 dB hearing level (HL); they did report a residue of the second harmonic at cancellation.

Theoretical models of traveling wave motion in the cochlea have been performed (6,7); these models show similar basilar membrane motion with both BC and AC stimulation. Von Békésy (8) demonstrated that, regardless

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