



Corridor of Comprehensive Knowledge

The Role of Direct Breastfeeding **in Shaping a Child's Dental Arch**





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Abstract

Human milk provides essential nutrients and immune protection and may also play a role in the development and function of the oral and maxillofacial complex. The coordinated activity of the tongue, lips, and mandible during direct breastfeeding has been associated with improved oral function and a lower prevalence of certain malocclusions. This problem-based article examines key mechanical features of breastfeeding, including subatmospheric pressure, soft-tissue deformation, milk flow, and oral-cavity volume changes. A step-by-step educational model is then used to explore pressure, force, flow rate, transferred milk volume, and dental-arch geometry. Although the selected relationships and numerical values are based on empirical measurements, the model remains a simplified representation of a complex biological system.

Note: This article is not intended to provide a specialized review of breastfeeding or any related recommendations. Rather, it aims to illustrate an interdisciplinary approach by integrating a dental topic with concepts from physics and mathematics. Following expert review and revision by specialists in dentistry, physics, and mathematics, the article will be published in a future issue of the Corridor of Comprehensive Knowledge Journal.

1) Background

Human milk provides infants with energy, macro- and micronutrients, and immune factors. Breastfeeding is associated with lower rates of some childhood infections and with several benefits for both mother and child [1]. However, receiving human milk and sucking directly at the breast are not exactly the same concept. An infant may receive expressed human milk by bottle and retain its nutritional and many biological benefits, but the patterns of tongue contact, jaw movement, soft-tissue deformation, and intraoral pressure differ from those of direct breastfeeding. This problem-based article therefore examines the mechanics of the mother–infant breastfeeding system using available scientific evidence and simplified physical models.

Successful breastfeeding requires the infant to maintain attachment, transfer milk through the oral cavity, swallow, and continue breathing. The system includes the tongue and mandible as moving structures, the palate as the upper boundary, the lips and cheeks as part of the seal, the nipple and areola as deformable tissues, milk as the fluid, and the mammary ducts as the transport network.

Table 1 introduces the main terms, followed by a review of the relevant research and the corresponding problem-based analysis.

**Table 1) Glossary of Terms Related to Teeth, Jaws, and Dental Occlusion**

English term	Simplified definition
Anterior open bite	A gap between the front teeth when the back teeth are closed
Arch width	The distance between the two sides of the dental arch
Bottle-feeding	Feeding an infant using a bottle and teat
Breastfeeding	Feeding an infant directly at the breast
Dental arch	The curved arrangement of teeth in each jaw
Malocclusion	Improper alignment or contact between the upper and lower teeth
Mandible	The movable bone of the lower jaw
Maxilla	The bone of the upper jaw
Nonnutritive sucking	Sucking without receiving milk or food, such as sucking a pacifier
Overjet	The horizontal distance between the upper and lower front teeth
Pacifier	A device used for nonnutritive sucking
Posterior crossbite	A condition in which one or more upper back teeth bite inside the lower back teeth
Primary dentition	The complete set of a child's primary teeth
Sucking pressure	Reduced pressure inside the mouth that helps milk transfer
Intraoral vacuum	Reduced pressure inside the mouth that helps milk transfer

2) Review of Selected Relevant Scientific Studies

This section examines several aspects relevant to the topic of the article on the basis of findings reported in previous studies.

2-1) Tongue Movement, Intraoral Vacuum, and Milk Transfer

To better understand how intraoral vacuum contributes to milk transfer, and to obtain realistic numerical values for infant feeding, we draw on the findings reported in Ref. [2], published by Geddes and colleagues in 2008. In this classic study, tongue movement during breastfeeding was recorded in 20 term infants using submental ultrasound, while intraoral pressure was measured simultaneously.

The study showed that when the posterior portion of the tongue moved downward, the volume of the oral cavity increased. As a result, intraoral pressure became more negative and milk flow was initiated. The mean baseline vacuum, which helps maintain attachment to the breast, was approximately -64 mmHg, whereas the mean peak vacuum at the lowest position of the tongue was approximately -145 mmHg. The mean milk intake during the monitored feeding session was 63 g, and the mean feeding duration was 8 min 16 s [2]. These values represent group means and may vary among infants, across ages, and during different stages of a feeding session.

In another study, direct breastfeeding was compared with feeding from an experimental teat designed to release milk in response to vacuum. The findings showed that baseline intraoral vacuum was stronger during breastfeeding than during feeding from the experimental teat, with mean values of -31 and -12 mmHg, respectively. A similar pattern was observed for peak vacuum, with corresponding values of -122 and -67 mmHg. In addition, as the tongue moved downward, thereby increasing oral-cavity volume and



vacuum magnitude, the mean increase in nipple diameter was 3.1 mm, compared with 1.5 mm for the experimental teat [3].

The greater intraoral vacuum observed during direct breastfeeding may be explained by the soft and deformable nature of breast tissue, which may require a larger pressure change to maintain attachment and facilitate milk transfer. By contrast, the experimental teat had a more stable shape and released milk at a lower vacuum. However, this explanation represents a mechanical interpretation, and the study did not independently establish the precise cause of the observed difference. Nevertheless, the findings indicate that even when milk release from a teat is vacuum-dependent, the magnitude of pressure and the extent of tissue deformation are not necessarily equivalent to those observed during direct breastfeeding. It should also be emphasized that the performance of the experimental teat used in this study should not be considered representative of all commercially available bottle teats.

2-2) Mechanical Benefits of Direct Breastfeeding: Relationship with Dental Arch Form

Movements of the tongue, jaw, and lips are repeated countless times throughout the months of breastfeeding. From a biological perspective, this sustained activity may form part of the functional environment in which the oral structures develop and may help exercise the muscles involved in sucking, swallowing, and breathing. Some dental studies have also reported that longer breastfeeding duration is associated with a lower likelihood of certain malocclusions in the primary dentition, including anterior open bite and posterior crossbite. However, Ref. [4] emphasizes that the available evidence relates mainly to the primary dentition, while convincing evidence for the mixed and permanent dentitions is still lacking. The same review also notes that differences in study design, together with factors such as genetics, tongue posture, breathing patterns, socioeconomic conditions, pacifier use, and digit sucking, make it difficult to draw firm causal conclusions.

Direct breastfeeding can therefore be considered mechanically different from feeding with a bottle teat and may provide a more favourable functional setting for the coordinated activity of the oral structures. Current evidence also links breastfeeding with certain favourable features of the primary dentition. Nevertheless, it is not yet possible to establish a precise relationship between the magnitude of sucking vacuum or pressure and the extent of jaw growth or widening.

These mechanical differences raise an important question: can the method of feeding influence dental development, particularly dental arch form and the way the upper and

lower teeth meet? To explore this question, the following section reviews findings from relevant dental studies.

The contact and relationship between the upper and lower teeth when the mouth is closed is known as occlusion. Malocclusion is the general term used for an unfavourable occlusal pattern. The outcomes considered in this review include increased overjet, in which the upper front teeth project farther forward horizontally; anterior open bite, in which a gap remains between the front teeth when the mouth is closed; and posterior crossbite, in which one or more upper posterior teeth are positioned inside the corresponding lower teeth. These conditions are related to dental arch form.

In a cross-sectional study of 851 children aged 2 to 5 years, Sum and colleagues found that children who had been exclusively breastfed for more than six months had greater mean intercanine and intermolar widths than children who had never been breastfed. After adjustment for age, sex, and non-nutritive sucking habits, the mean distances between corresponding canine teeth and between corresponding molar teeth on opposite sides of the arch were 0.608 mm and 0.857 mm greater, respectively, among children exclusively breastfed for more than six months [5].

After adjustment for age, sex, pacifier use, and digit sucking, the odds of having an overjet greater than 3.5 mm were approximately 49% lower among children exclusively breastfed for more than six months than among those who had never been breastfed [5].

In a birth-cohort-based longitudinal study in Pelotas, Brazil, 1,303 children were examined at 5 years of age. The prevalence of anterior open bite was 33% lower among children who had been exclusively breastfed from 3 months to just under 6 months, and 44% lower among those exclusively breastfed for at least 6 full months. For moderate or severe malocclusion, the corresponding prevalences were 41% and 72% lower than among children who had not been breastfed. The researchers adjusted their models for age, sex, and sucking habits; however, the study design and statistical methods cannot eliminate all uncertainty from the findings [6].

A meta-analysis (an analysis combining findings from multiple independent studies on the same topic) by Peres and colleagues combined the available evidence and found that exclusive breastfeeding and longer breastfeeding duration were associated with a lower likelihood of malocclusion in the primary dentition [7]. A further meta-analysis by Boronat-Catalá and colleagues reported that longer breastfeeding duration was associated with a lower likelihood of posterior crossbite. This wording indicates a statistical association and does not imply that breastfeeding alone prevents the condition. Although 31 studies were

reviewed qualitatively, only nine provided sufficiently comparable numerical data to be combined in the meta-analysis [8].

Not all studies have produced the same findings. A 2024 study found no significant association between breastfeeding or its duration and posterior crossbite. Longer bottle-feeding duration, however, was associated with a greater occurrence of this condition [9]. A careful review of the evidence therefore suggests that the most defensible conclusion is that longer breastfeeding duration is associated with the preservation of certain favourable features of the primary dentition. However, there is still no conclusive evidence that breastfeeding itself determines a specific pattern of jaw development that persists beyond childhood [4].

3) Conclusions and Directions for Future Research

The literature suggests that direct breastfeeding is not simply a means of delivering milk to the infant. It is a coordinated mechanical process involving the tongue, mandible, lips, cheeks, swallowing, and breathing. As the infant lowers the tongue, the volume of the oral cavity increases and intraoral pressure falls below atmospheric pressure. The resulting pressure difference, together with mandibular movement and deformation of the soft breast tissue, draws milk into the mouth [10,11]. During each sucking cycle, the breast adapts to the shape of the infant's mouth, tongue movement, and the pressure generated. This distinguishes direct breastfeeding from feeding with an artificial teat, whose shape, material, stiffness, and milk-release mechanism are predetermined and cannot fully reproduce the mechanical behaviour of living breast tissue.

Comparative studies have shown that patterns of intraoral pressure and nipple deformation differ between direct breastfeeding and feeding with an experimental teat. During direct breastfeeding, the infant plays a more active role in generating milk flow, and milk transfer depends on coordinated and rhythmic oral movements. The tongue and jaw therefore do more than move milk; they continuously participate in a cycle of sucking, milk intake, swallowing, and breathing. This repeated activity creates a functional environment for the muscles of the oral and facial complex. Dental studies have also associated longer breastfeeding duration with certain favourable features of the primary dentition, including greater mean values for some transverse dimensions of the dental arch and a lower likelihood of certain unfavourable occlusal patterns. Direct breastfeeding may therefore provide a more adaptive and coordinated pattern of oral activity than teat feeding. Nevertheless, final jaw and dental development is influenced by many factors, including



genetics, breathing pattern, tongue posture, facial growth, diet, pacifier use, and digit sucking.

Future studies should examine the mechanics of feeding separately in clearly defined groups, including direct breastfeeding, bottle-feeding with expressed human milk, and formula feeding. This would help distinguish the effects of milk composition from those of the sucking method itself. Commercial teats with different shapes, materials, and flow rates should also be compared with the natural breast. Simultaneous measurement of intraoral pressure, tongue movement by ultrasound, muscle activity, nipple deformation, and milk flow could provide a more complete understanding of the feeding process. Longitudinal follow-up of the same children from infancy through the development of the primary and permanent dentitions, together with three-dimensional imaging of the dental arches, is also needed to clarify the long-term relationship between sucking patterns and oral development.

An important practical direction is the development of educational and laboratory systems for demonstrating breastfeeding mechanics. Such a system could include a transparent model of the oral cavity, a movable tongue, soft materials with properties similar to breast tissue, interchangeable teats, and pressure and flow sensors. By displaying tongue movement, pressure changes, and fluid flow simultaneously, this type of model would allow students and researchers to observe, measure, and compare the mechanical behaviour of the natural breast and artificial teats, while also supporting the development of new hypotheses for future research.

4) Quantitative Framework Used in the Problem

The concepts presented below are required to answer the questions posed in the problem.

Pressure Conversion and Cyclic Pressure Change

The pressure inside the infant's mouth is measured relative to ambient air pressure. The difference between these two pressures is denoted by ΔP :

$$\Delta P = P_{\text{oral}} - P_{\text{atm}}$$

In this relationship, P_{oral} represents intraoral pressure and P_{atm} represents atmospheric pressure. During sucking, intraoral pressure is lower than ambient pressure; therefore, ΔP is negative and represents the intraoral vacuum. To compare vacuum strength, the absolute magnitude of the pressure difference, $|\Delta P|$, is used.

The pressure values reported in the studies used in this article are expressed in millimetres of mercury. They are converted to the standard unit of pascals using the following relationship:



$$1 \text{ mmHg} = 133.322 \text{ Pa}$$

Baseline vacuum is denoted by P_{base} and peak vacuum by P_{peak} . Baseline vacuum helps maintain the infant's attachment to the breast, whereas peak vacuum occurs when the tongue moves downward and milk transfer increases. The magnitude of the pressure change during one sucking cycle is calculated as:

$$\Delta P_{\text{cycle}} = |P_{\text{peak}} - P_{\text{base}}|$$

This quantity is used to compare the change in pressure generated during sucking at the breast and at the experimental teat.

Equivalent Resultant Force Associated with Pressure

To illustrate the relationship between pressure and force, a hypothetical effective area, denoted by S_{eff} , is introduced. The equivalent resultant force associated with pressure is calculated as:

$$F = |\Delta P| S_{\text{eff}}$$

In this relationship, F is the equivalent resultant force, $|\Delta P|$ is the magnitude of the pressure difference, and S_{eff} is the assumed effective area. This calculation only shows the force corresponding to a given pressure difference if that pressure were applied uniformly over a specified area. The resulting value is not a direct measurement of the force produced by the tongue, lips, or mandible, nor does it represent the force applied to the jawbone.

Pressure Change over Time

Intraoral pressure does not remain constant during sucking. Within each cycle, it changes from the baseline value to the peak value and then returns to baseline. Pressure is therefore represented as a function of time, denoted by $P(t)$.

If f is the number of sucking cycles per minute, the duration of each cycle, or period T , is calculated as:

$$T = \frac{60}{f}$$

In this relationship, f is expressed in cycles per minute and T in seconds. The quantity $\frac{dP}{dt}$, the derivative of pressure with respect to time, represents the rate at which intraoral pressure changes. The pressure-time quantity for the first half of a cycle is defined as:

$$I_p = \int_0^{T/2} |P(t) - P_{\text{base}}| dt$$

The area between the pressure curve and the baseline-pressure line during the first half of the cycle, I_p , describes both the magnitude and duration of the increase in vacuum as



milk enters the mouth. Similar pressure–time quantities have been used in breastfeeding research to examine the relationship between sucking-cycle characteristics and milk transfer [12]; however, in this article, I_p is used as an educational descriptor and is not an indicator for predicting jaw growth.

Milk Transfer

The volumetric flow rate of milk is denoted by Q . In a simplified hydraulic model, flow rate is directly related to the pressure difference and inversely related to the resistance of the flow pathway:

$$Q = \frac{|\Delta P|}{R_h}$$

In this relationship, R_h represents the effective hydraulic resistance of the milk-flow pathway. Here, ΔP is treated as an approximation of the effective pressure difference driving the flow.

This equation is included in the problem to compare the role of pressure difference in milk transfer. When the breast and the teat are compared, assuming the same R_h is only an educational simplification, because the shape, flexibility, and opening behaviour of the milk pathway differ between the two conditions and cannot be considered physically identical.

If m is the mass of milk, V its volume, and ρ its density, then:

$$V = \frac{m}{\rho}$$

$\bar{Q}$, the mean volumetric transfer rate during a feeding session, is calculated by dividing the total milk volume by the duration of the feeding session, t_{feed} :

$$\bar{Q} = \frac{V}{t_{\text{feed}}}$$

If the sucking frequency is f cycles per minute, the mean volume transferred per cycle is calculated as:

$$V_{\text{cycle}} = \frac{\bar{Q}}{f}$$

This value represents an average over the entire feeding session and differs from the instantaneous milk flow during an individual suck.

Statistical Comparison of Dental Outcomes

For the analysis of dental data, the breastfeeding group is identified by the subscript B , and the group with no history of breastfeeding by the subscript N .



x_B represents the number of children with the dental outcome in the breastfeeding group, and n_B represents the total number of children in that group. Similarly, x_N and n_N refer to the group with no history of breastfeeding. The observed prevalence in each group is calculated as:

$$p_B = \frac{x_B}{n_B}$$

$$p_N = \frac{x_N}{n_N}$$

P_R , the crude prevalence ratio, is obtained by comparing these two prevalences:

$$P_R = \frac{p_B}{p_N}$$

R_{PR} , the relative prevalence reduction, is given by:

$$R_{PR} = 1 - P_R$$

O_R , the crude odds ratio, is calculated as:

$$O_R = \frac{x_B/(n_B - x_B)}{x_N/(n_N - x_N)}$$

These measures indicate the strength of the statistical association between breastfeeding history and the dental outcome, but they do not, by themselves, establish a causal relationship.

Geometric Model of the Dental Arch

To provide a simple comparison of dental-arch shape, the maxillary arch is modelled as a semi-ellipse. Arch width is denoted by W , the assumed arch depth by D , and the area of the semi-elliptical model by S_{arch} :

$$S_{\text{arch}} = \frac{\pi WD}{4}$$

This relationship is used to convert differences in arch width into a visually interpretable geometric comparison. The percentage difference in width between the two groups is calculated as:

$$\% \Delta W = \frac{W_B - W_N}{W_N} \times 100$$

In this relationship, W_B is the mean arch width in the breastfeeding group, and W_N is the mean arch width in the group with no history of breastfeeding. It should be emphasized that the semi-elliptical model is a two-dimensional educational approximation. The actual dental arch is three-dimensional, asymmetrical, and dependent on age and on the anatomical reference points used for measurement.

Table 2 contains both values published in research articles and hypothetical educational values used in constructing the problem.

Table 2) Published Data and Hypothetical Educational Values

Quantity	Value Used	Status and Source
Mean baseline vacuum at the breast	-64 mmHg	Published mean [2]
Mean peak vacuum at the breast	-145 mmHg	Published mean [2]
Mean baseline vacuum with the experimental teat	-12 mmHg	Published comparison [3]
Mean peak vacuum with the experimental teat	-67 mmHg	Published comparison [3]
Breast baseline vacuum (comparison study)	-31 mmHg	Published comparison [3]
Breast peak vacuum (comparison study)	-122 mmHg	Published comparison [3]
Nipple / experimental teat expansion	3.1 mm / 1.5 mm	Published comparison [3]
Mean milk intake and feeding duration	63 g, 8 min 16 s	Published means [2]
Sucking frequency used in the model	80 cycles/min	Educational assumption within reported ranges
Effective area under pressure	1.50 cm ²	Educational assumption
Milk density	1.00 g/mL	Approximation used for volume conversion
Inter canine width: >6 months / never	31.50 / 30.93 mm	Descriptive means [5]
Inter molar width: >6 months / never	45.25 / 44.50 mm	Descriptive means [5]
Cases of increased overjet	23/192 vs 49/236	Descriptive counts [5]
Arch depth in the geometric model	20.0 mm	Educational assumption (same in both groups)

5) Problem Statement

Note: In constructing the problem, all numerical examples taken from research studies are accompanied by citations. Values labelled “educational assumption” are modelling choices.

This section presents the scientific and educational questions related to the topic of the article.

A) Pressure Conversion and Cyclic Pressure Change

Using the conversion 1 mmHg = 133.322 Pa:

1. Convert the mean baseline and peak intraoral vacuum values during breastfeeding to kilopascals.
2. Calculate the magnitude of the pressure change over a complete sucking cycle.

B) Calculation of the Resultant Force

Assume that the pressure difference acts uniformly over an effective area of 1.50 cm².

Calculate:

1. The resultant force corresponding to the peak vacuum.
2. The change in resultant force from baseline to peak pressure.

Explain why these values are not direct measurements of tongue force or of the force applied to the developing maxillary bone.

**C) Comparison of the Breast and the Experimental Teat**

Using the data for the breast and the experimental teat reported in Ref. [3]:

1. Calculate the pressure-cycle amplitude for each condition.
2. Assuming that the effective hydraulic resistance is the same in both conditions, estimate the ratio of the pressure-driven flow amplitudes.
3. Calculate the percentage by which nipple expansion exceeded the expansion of the experimental teat.

D) Time-Dependent Pressure Model

At a frequency of 80 cycles per minute, let T denote the period and model one cycle as follows:

$$P(t) = -64 - 81\sin^2\left(\frac{\pi t}{T}\right), \quad 0 \leq t \leq T,$$

In the given equation, pressure is expressed in millimetres of mercury.

1. Calculate T .
2. Differentiate $P(t)$ and determine the maximum magnitude of dP/dt .
3. Calculate the additional pressure-time area below the baseline during the first half of the cycle:

$$I_P = \int_0^{T/2} |P(t) + 64| dt.$$

Interpret I_P as an exposure-like descriptor rather than a validated predictor of jaw growth.

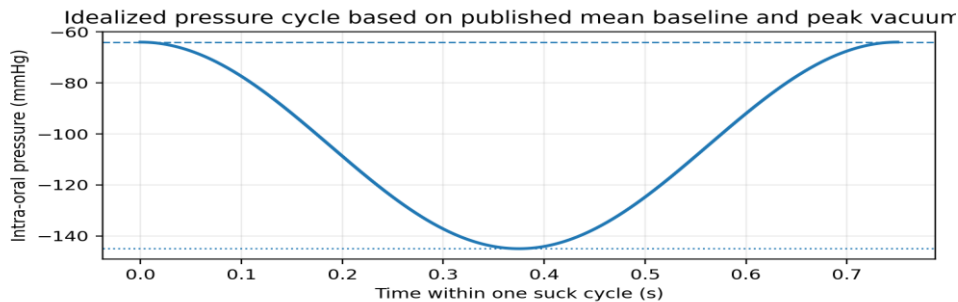


Figure 1) Idealized Pressure Cycle

E) Mean Milk-Transfer Rate

Using the reported mean intake of 63 g of milk over 8 min 16 s [2], estimate the following:

1. The mean mass-transfer rate in grams per second.
2. The mean volumetric transfer rate in millilitres per minute, assuming a density of 1.00 g/mL,



3. The mean volume transferred per suck at a frequency of 80 cycles per minute.

Why does this whole-feed average differ from the instantaneous flow of milk?

F) Analysis of Published Dental Data

Using the increased-overjet data reported by Sum et al. [5]:

- Exclusive breastfeeding for more than 6 months: 23 cases among 192 children.
- No history of breastfeeding: 49 cases among 236 children.

Calculate:

1. The prevalence in each group.
2. The crude prevalence ratio and relative prevalence reduction.
3. The crude odds ratio.
4. Compare the crude odds ratio with the published adjusted odds ratio of 0.511.

G) Dental-Arch Geometry

Model the maxillary arch as a semi-ellipse with width W and an assumed depth of $D = 20.0$ mm (as stated previously, $S = \frac{\pi WD}{4}$):

1. Using the published mean intermolar widths of 45.25 and 44.50 mm [5], calculate the idealized arch area.
2. Determine the difference in area and the percentage difference.
3. Also calculate the percentage difference directly for the intercanine and intermolar widths.
4. Explain why the semi-elliptical model is useful but biologically incomplete.

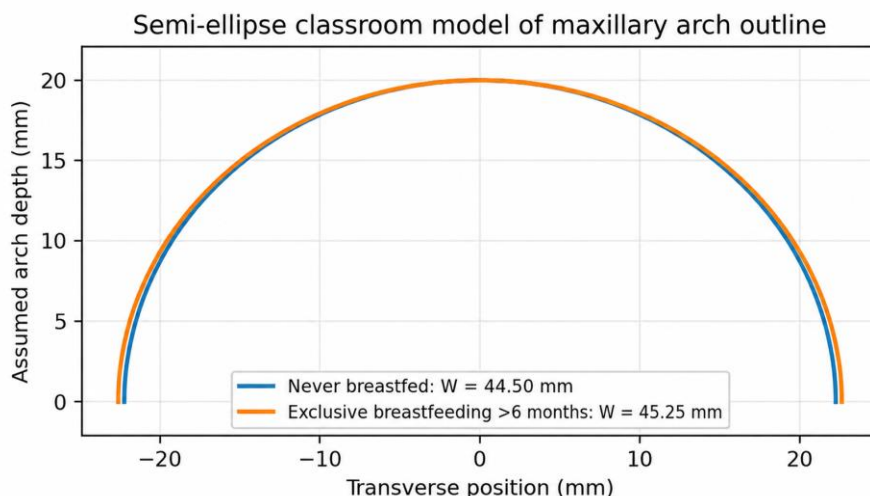


Figure 2) Semi-Elliptical Model of the Dental Arch

6) Detailed Solutions to the Problems

A) Pressure Conversion

$$P_{\text{baseline}} = -64(133.322) = -8532.6 \text{ Pa} \approx -8.53 \text{ kPa}.$$



$$P_{\text{peak}} = -145(133.322) = -19331.7 \text{ Pa} \approx -19.33 \text{ kPa.}$$

The magnitude of the cyclic pressure change is:

$$\Delta P_{\text{cycle}} = (145 - 64) \text{ mmHg} = 81 \text{ mmHg} \approx 10.80 \text{ kPa.}$$

B) Idealized (Modelled) Resultant Force Due to Pressure

Area conversion:

$$1.50 \text{ cm}^2 = 1.50 \times 10^{-4} \text{ m}^2.$$

At peak vacuum:

$$F_{\text{peak}} = |P_{\text{peak}}|S_{\text{eff}} = (19,331.7)(1.50 \times 10^{-4}) \approx 2.90 \text{ N.}$$

The cyclic change is:

$$\Delta F = \Delta P_{\text{cycle}}S_{\text{eff}} = (10.8 \times 10^3)(1.50 \times 10^{-4}) \approx 1.62 \text{ N.}$$

These values estimate the resultant force associated with pressure acting over a hypothetical area. The actual forces generated by the tongue, lips, cheeks, mandible, and tissue contact are distributed, directional, time-varying, and partly balanced within the system. Therefore, $F = |\Delta P|S_{\text{eff}}$ should not be presented as a directly measured force that deforms bone.

C) Comparison with the Experimental Teat

Pressure amplitude at the breast:

$$122 - 31 = 91 \text{ mmHg.}$$

Pressure amplitude with the experimental teat:

$$67 - 12 = 55 \text{ mmHg.}$$

Under the deliberate simplifying assumption that the resistance is the same in both cases:

$$\frac{Q_{\text{breast}}}{Q_{\text{teat}}} \approx \frac{91}{55} \approx 1.65.$$

This calculation compares pressure amplitudes rather than measured flow rates, because resistance, opening behaviour, and geometry differ between the two conditions.

Comparison of tissue expansion:

$$\frac{3.1}{1.5} = 2.07,$$

$$\frac{3.1 - 1.5}{1.5} \times 100\% \approx 106.7\%.$$

Thus, in that study, the measured expansion of the nipple was approximately 2.07 times that of the experimental teat [3].

D) Pressure Waveform and Calculus

The period is:



$$T = \frac{60}{80} = 0.75 \text{ s.}$$

Differentiating gives:

$$\frac{dP}{dt} = -81 \frac{\pi}{T} \sin\left(\frac{2\pi t}{T}\right).$$

The maximum magnitude of the time derivative occurs when the absolute value of the sine term is 1:

$$\max \left| \frac{dP}{dt} \right| = 81 \frac{\pi}{0.75} \approx 339.3 \text{ mmHg/s.}$$

In SI units:

$$339.3(0.133322) \approx 45.2 \text{ kPa/s.}$$

The pressure-time area is:

$$I_p = 81 \int_0^{T/2} \sin^2\left(\frac{\pi t}{T}\right) dt = 81 \frac{T}{4}.$$

$$I_p = 81 \left(\frac{0.75}{4}\right) = 15.1875 \text{ mmHg}\cdot\text{s} \approx 2.025 \text{ kPa}\cdot\text{s}.$$

This curve is an educational waveform bounded by the published mean baseline and peak pressures. Actual infant pressure traces are not perfectly sinusoidal, and I_p has not been validated as a predictor of dental-arch growth.

E) Milk Transfer Rate

Time conversion:

$$8 \text{ min } 16 \text{ s} = 496 \text{ s.}$$

Mean mass-transfer rate:

$$\dot{m} = \frac{63}{496} \approx 0.127 \text{ g/s.}$$

With $\rho \approx 1.00 \text{ g/mL}$,

$$\dot{V} \approx 0.127 \text{ mL/s} = 7.62 \text{ mL/min.}$$

At a frequency of 80 cycles per minute, the mean volume transferred per cycle is:

$$V_{\text{cycle}} = \frac{7.62}{80} \approx 0.095 \text{ mL/cycle.}$$

This value is an average over the entire feeding session. Instantaneous flow is pulsatile, varies among milk ejections, and is affected by swallowing pauses and changes in vacuum [2,12].

F) Epidemiological Calculations

Observed prevalences:



$$p_{>6} = \frac{23}{192} = 0.1198 \approx 12.0\%,$$

$$p_{\text{never}} = \frac{49}{236} = 0.2076 \approx 20.8\%.$$

Crude prevalence ratio:

$$P_R = \frac{0.1198}{0.2076} \approx 0.577.$$

Relative prevalence reduction:

$$R_{PR} = 1 - P_R \approx 0.423 = 42.3\%.$$

Crude odds ratio:

$$O_R = \frac{23/169}{49/187} = \frac{23 \times 187}{169 \times 49} \approx 0.519.$$

The crude odds ratio of 0.519 is close to the study's published adjusted odds ratio of 0.511. The adjusted model accounted for age, sex, digit sucking, and pacifier use [5]. None of these estimates establishes causality. In addition, an odds ratio should not be interpreted as a prevalence ratio without careful qualification.

G) Semi-Elliptical Model

For $W = 45.25$ mm and $D = 20.0$ mm:

$$S_{>6} = \frac{\pi(45.25)(20.0)}{4} \approx 710.8 \text{ mm}^2.$$

For $W = 44.50$ mm:

$$S_{\text{never}} = \frac{\pi(44.50)(20.0)}{4} \approx 699.0 \text{ mm}^2.$$

Difference:

$$\Delta S \approx 11.8 \text{ mm}^2.$$

Percentage difference:

$$\frac{11.8}{699.0} \times 100\% \approx 1.69\%.$$

Comparison of widths:

$$\frac{31.50 - 30.93}{30.93} \times 100\% \approx 1.84\% \quad (\text{intercanine}),$$

$$\frac{45.25 - 44.50}{44.50} \times 100\% \approx 1.69\% \quad (\text{intermolar}).$$

The semi-ellipse makes the geometry transparent; however, the actual dental arch is three-dimensional, asymmetrical, and age-dependent, and cannot be defined by a single width and an assumed depth alone.

**Table 3) Curriculum Alignment with Secondary-School Learning Standards
(British Columbia as an Example)**

Course	Related Learning Standards and Competencies	Application in This Article
Mathematics 10–11 / Pre-Calculus 11–12	Unit conversion, ratios, percentages, functions, and modelling in real-world contexts	Conversion of mmHg to Pa, proportional comparisons, semi-ellipse model, percentage differences
Calculus 12	Instantaneous rate of change, differentiation, definite integrals, area under a curve, contextual modelling [13]	dP/dt , Maximum rate of pressure change, pressure–time integral
Statistics 12	Critical appraisal of studies, identifying limitations and confounding factors, valid conclusions, presenting data in tables and graphs [14]	Prevalence, P_R , and O_R , adjusted versus crude estimates, statistical association versus causation
Physics 11–12	Forces, SI units, uncertainty, model evaluation, and data processing [15]	Pressure, $F = \Delta P S_{\text{eff}}$, hydraulic-resistance analogy; assumptions and uncertainty
Anatomy and Physiology 12	Organ systems, structure–function relationships, limitations of models, ethical data collection [16]	Tongue, mandible, oral cavity, swallowing, and craniofacial growth
Chemistry 11 / Specialized Science 12	Intermolecular behaviour, fluids and material properties, dimensional analysis, interdisciplinary research [17,18]	Milk rheology, flexible tissue, Newtonian versus non-Newtonian modelling

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